User Manual

Model T750
Portable Calibrator

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IMPORTANT SAFETY INFORMATION

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 placed throughout this manual and inside the instrument. The symbols with messages are defined 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

For Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product, please contact Teledyne API's Technical Support Department:

Telephone: 800-324-5190 Email: sda_techsupport@teledyne.com

or by accessing various service options on our website:

http://www.teledyne-api.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!

WARRANTY

WARRANTY POLICY (02024G)

Teledyne API (TAPI), a business unit of Teledyne Instruments, Inc., provides that:

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

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting are to be performed by the customer.

NON-TAPI MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

PRODUCT RETURN

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

The complete Terms and Conditions of Sale can be reviewed at http://www.teledyne-api.com/terms_and_conditions.asp

CAUTION – Avoid Warranty Invalidation

Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to the manual, Fundamentals of ESD, PN 04786, in its "Packing Components for Return to Teledyne API's Customer Service" section. The manual can be downloaded from our website at http://www.teledyne-api.com under Help Center>Product Manuals in the Special Manuals section; RMA procedures are under Help Center>Return Authorization.

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REVISION HISTORY

This section provides information regarding the initial release and subsequent changes to this manual.

T750 Manual, PN 08070			
Date	**Rev**	**DCN**	**Change Summary**
11 Feb 2015	A	6841	Initial Release

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1. INTRODUCTION

This section provides an overview of the Model T750 portable calibrator, its features, and its options.

1.1. T750 CALIBRATOR OVERVIEW

Teledyne API's Model T750 (typically referred to as T750) is a portable, microprocessor-controlled calibrator for precision gas calibrators. Using a combination of highly accurate mass flow controllers and compressed sources of standard gases, calibration standards are provided for multipoint span and zero checks.

The T750 can be equipped with an optional, built-in, programmable ozone generator for accurate, dependable ozone calibrations. The T750 also produces NO_2 when blended with NO gas in the internal GPT chamber. A multi-point linearization curve is used to control the generator to assure repeatable ozone concentrations. An optional photometer allows precise control of the ozone generator, both during calibrations and during Gas Phase Titrations (GPT). To ensure accurate NO_2 output, the calibrator with photometer option measures the ozone concentration prior to doing a GPT.

As many as 50 independent calibration sequences may be programmed into the T750, covering time periods of up to one year. Sequence setup is simple and intuitive, and they may be actuated manually, automatically, or by a remote signal. The sequences may be uploaded remotely, including remote editing. All programs are maintained in non-volatile memory.

The T750 provides fast response, repeatability, overall accuracy and ease of operation, and may be combined with a Teledyne API Zero Air Generator to provide the ultimate in easy to use, precise calibration for your gas calibrators.

1.2. FEATURES

Some of the exceptional features of your T750 Portable Calibrator are:

- Advanced T-Series electronics
- LCD color graphics display with touchscreen interface
- Microprocessor control for versatility
- Bi-directional USB (optional), RS-232, optional RS-485, and 10/100Base-T Ethernet for remote operation
- Precise calibration gas generation for Ozone, NO, NO_2, CO, HC, H_2S, SO_2
- 12 independent timers for sequences
- Nested sequences (up to 5 levels)

- Software linearization of Mass Flow Controllers (MFC)
- Calibration gas port configurable for single or multi-blend gases
- Optional 3rd MFC for wide dynamic range
- Optional gas phase titration chamber
- Optional ozone generator and photometer to allow use as primary or transfer standard
- Inlets for external ozone reference sources

CAUTION – GENERAL SAFETY HAZARD

THE T750 PORTABLE CALIBRATOR WEIGHS 21.14KG (46.6POUNDS) WITH ALL OPTIONS. TO AVOID PERSONAL INJURY WE RECOMMEND THAT TWO PERSONS LIFT AND CARRY IT BY FIRST DISCONNECTING ALL CABLES AND TUBING FROM THE CALIBRATOR BEFORE MOVING IT.

2. SPECIFICATIONS AND APPROVALS

2.1. SPECIFICATIONS

Table 2-1: T750 Dilution System Specifications

Parameter	Specification
Flow Measurement Accuracy	± 1.0% of Full Scale
Repeatability of Flow Control	± 0.2% of Full Scale
Linearity of Flow Measurement	± 0.5% of Full Scale
Flow Range of Diluent Air	0 to 10 SLPM – Optional Ranges: 0 to 5 SLPM; 0 to 20 SLPM
Flow Range of Cylinder Gases	0 to 100 cc/min – Optional Ranges: 0 to 50 cc/min; 0 to 200 cc/min
Zero Air Required	10 SLPM @ 30 PSIG Optional: 20 SLPM @ 30 PSIG
CAL Gas Input Ports	1 (configurable)
Diluent Gas Input Ports	1
Response Time	60 Seconds (98%)

Table 2-2: T750 Electrical and Physical Specifications

Parameter	Specification	
AC Power	Rating	Typical Power Consumption
	100-240 V~ 50/60 Hz, 1.5 A	115 V: 76 W 230 V: 80 W
Analog Outputs	1 user configurable output	
Analog Output Ranges (Test Channel)	10V, 5V, 1V, 0.1V (selectable) Range with 5% under/over-range	
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 digital control outputs 12 digital control inputs 8 digital status outputs	
Optional I/O	1 USB com port 1 RS485 Multidrop RS232	
Operating Temperature Range	5-40ºC	
Humidity Range	0 - 95% RH, non-condensing	

Parameter	Specification
Environmental Conditions	Installation Category (Over Voltage Category) II Pollution Degree 2 Intended for Indoor Use Only at Altitudes ≤ 2000m
Materials	Cal Gas Output Wetted Surfaces: PTFE. Cal Gas Output Manifold: Glass-coated Steel
Dimensions (H x W x D)	9" x 17" x 21" (229 mm x 432 mm x 533 mm)
Weight	37 lbs (16.78 kg); 46.6 lbs (21.14 kg) with optional photometer, GPT, and O_3 generator

Table 2-3: T750 Specifications for Optional Ozone Generator

Parameter	Specification
Maximum Output	6 ppm LPM
Minimum Output	100 ppb LPM
Response Time:	180 seconds to 98%
Optical Feedback	Standard
Stability (7 days)	1% with photometer option 3% without photometer option
Linearity	1% with photometer option 3% without photometer option

Table 2-4: T750 Specifications for Optional O_3 Photometer

Parameter	Specification
Full Scale Range	100 ppb to 10 ppm ; User Selectable
Precision	1.0 ppb
Linearity	1.0% of reading
Rise/Fall Time	<20 sec (photometer response)
Response Time (95%)	180 sec. (system response)
Zero Drift	<1.0 ppb / 24 hours
Span Drift	<1% / 24 hours
Minimum Gas Flow Required	800 cc/min

2.2. APPROVALS AND CERTIFICATIONS

The Teledyne API Model T750 calibrator was tested and certified for Safety and Electromagnet Compatibility (EMC). This section presents the compliance statements for those requirements and directives.

2.2.1. SAFETY

IEC/EN 61010-1:2010 (3rd Edition), Safety requirements for electrical equipment for measurement, control, and laboratory use.

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

2.2.2. **EMC**

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

EN55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

CE: 2004/108/EC, Electromagnetic Compatibility Directive

2.2.3. **OTHER TYPE CERTIFICATIONS**

For additional certifications, please contact Technical Support.

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3. GETTING STARTED

This section addresses the procedures for unpacking the instrument and inspecting for damage, introduces the instrument layout, and presents the procedures for getting started: making communications and pneumatic connections, and conducting an initial calibration check.

3.1. UNPACKING AND INITIAL SETUP

CAUTION – RISK of Personal Injury

THE T750 WEIGHS 21.14 KG (46.6 POUNDS) WITH ALL OPTIONS. TO AVOID PERSONAL INJURY, USE TWO PERSONS TO LIFT AND CARRY THE CALIBRATOR.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges (ESD) too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, see *Fundamentals of ESD* manual, PN 04786, available on our website at http://www.teledyne-api.com under Help Center>Product Manuals in the Special Manuals section.

CAUTION – Avoid Damage to the Instrument

BEFORE operating instrument, remove dust plugs from pneumatic ports.

NEVER allow instrument to run with the case closed – keep lid open to vent while operating.

NEVER attempt to lift the T750 by the interior handles attached to the control/display and input panel.

Note

Although this product is portable, it must be properly packaged any time it ships for any reason; it is recommended that you store shipping containers/materials for such use. See Warranty page in this manual and shipping procedures on our Website at http://www.teledyne-api.com under Customer Support>Return Authorization.

WARNING!

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

1. Verify that there is no shipping damage. If there are signs of damage, immediately advise the shipper, then Teledyne API.
2. Remove the T750 from its shipping carton.
3. Open the lid and check for damage inside.
4. Check the line voltage and frequency label on the instrument to ensure that it matches the local power source.

3.2. INSTALLATION

The T750 is a portable, self-contained instrument; there are no installation instructions other than to ensure that the cooling fan/vents are not blocked; the vents are provided by a grill around the sides, visible when the case is open. Also, ensure that there is adequate support for the calibrator's weight.

3.3. CALIBRATOR LAYOUT

Figure 3-1 shows the calibrator's control panel layout, followed by a close-up of the display/touchscreen in Figure 3-2 and description in Table 3-1. The two USB ports on the control panel are provided for the connection of peripheral devices:

- plug-in mouse (not included) to be used as an alternative to the touchscreen interface
- flash drive (not included) to download updates to instruction software (contact TAPI Technical Support for information).

3.3.1. CONTROL AND INPUT PANEL

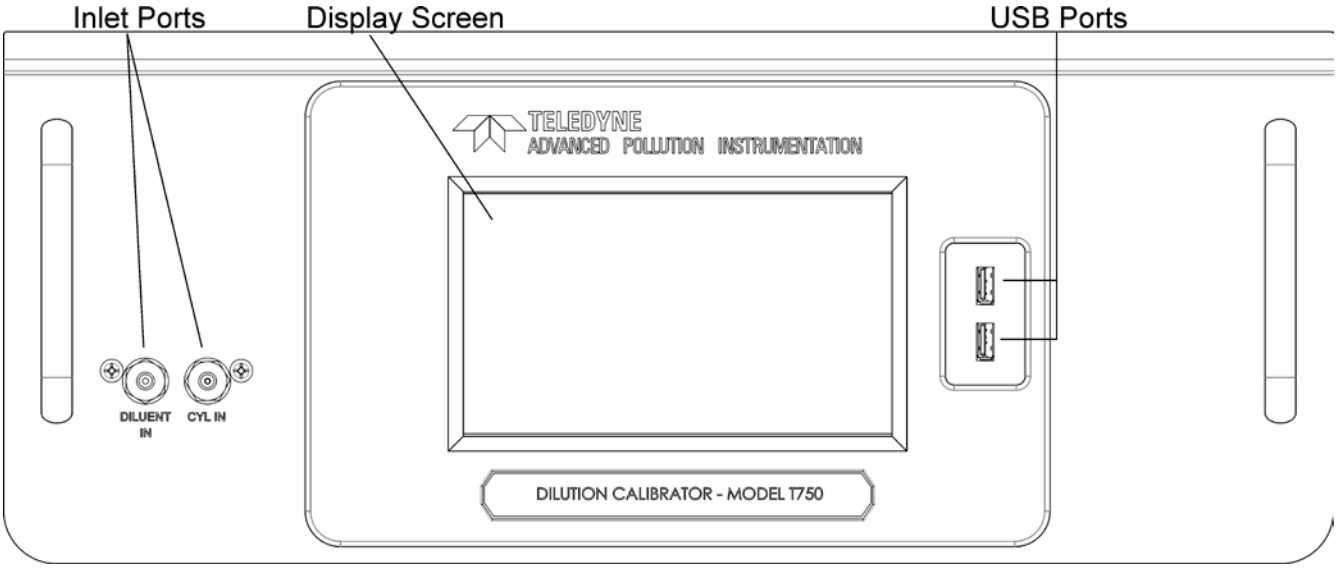


Figure 3-1: T750 Control/Display and Input Panel

Figure 3-2: LCD Display and Touchscreen Control

The control panel liquid crystal display (LCD) screen includes touch control. Upon calibrator start-up, the LCD display shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above.

CAUTION – Avoid Damaging Touchscreen
Do not use hard-surfaced instruments such as pens to operate the touch screen buttons.

Table 3-1: Display Screen and Touch Control Description

Field	Description/Function			
LEDs indicating the states of the calibrator:				
	Name	Color	State	Definition
	Active	Green	off	Unit is operating in STANDBY mode. This LED is lit when the instrument is actively producing calibration gas (GENERATE mode).
	Auto Timer	Yellow	off	This LED is lit only when the calibrator is performing an automatic calibration sequence.
	Fault	Red	blinking	The calibrator is warming up and therefore many of its subsystems are not yet operating within their optimum ranges. Various warning messages may appear in the Param field.
Target/ Actual	Gas concentrations, Cal gas MFC and Diluent MFC values with unit of measure			
Mode	Displays the name of the calibrator's current operating mode (default is STANDBY at initial startup).			
Param	Displays a variety of informational messages, such as warnings, operational data, test function values and responses during interactive tasks.			
Touchscreen control: row of eight buttons with dynamic, context sensitive labels; buttons are blank when inactive/inapplicable.				

Figure 3-3 shows how the control panel display is mapped to the menu charts that are illustrated throughout this manual. The Mode, Param (parameters), and Target/Actual (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.

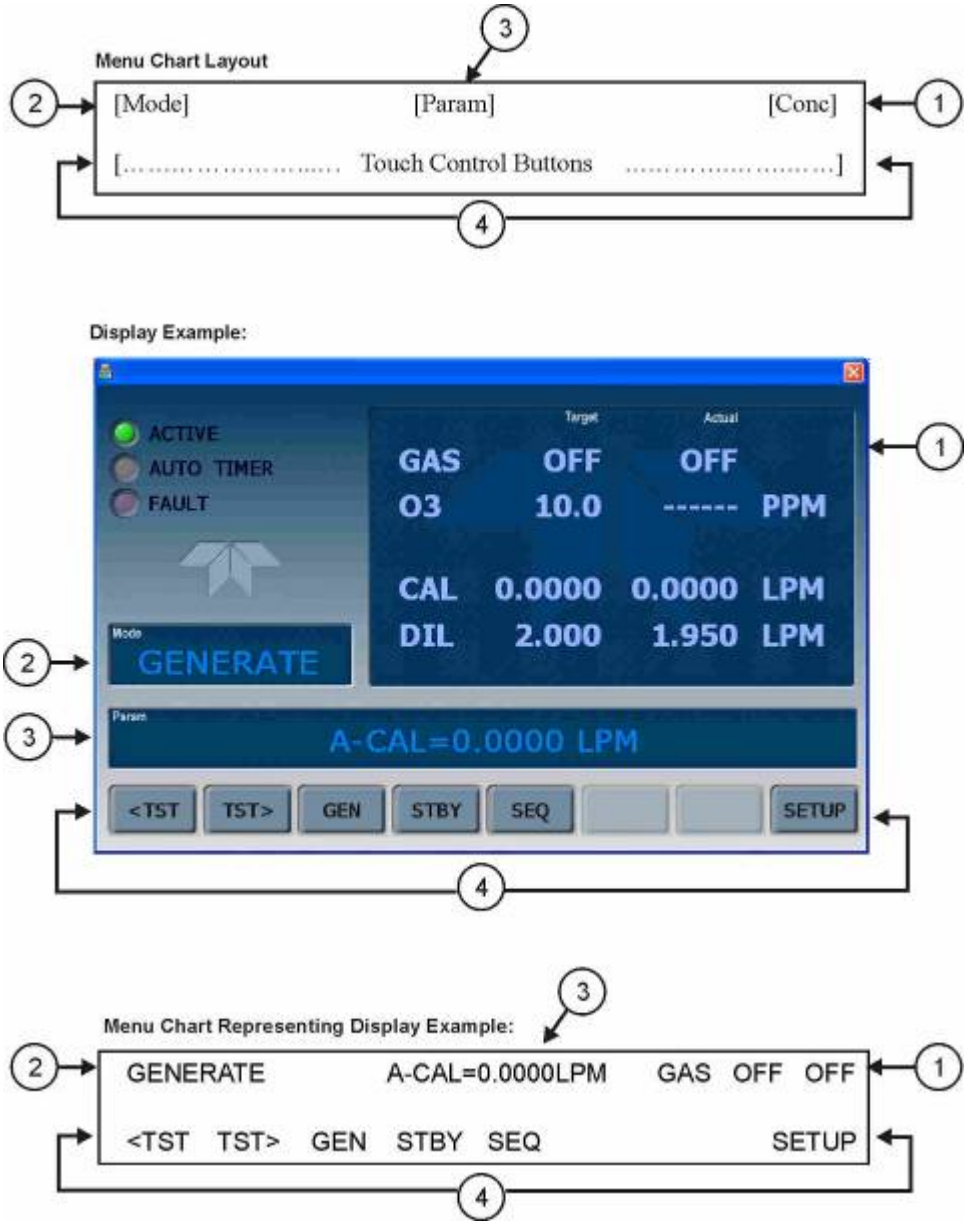


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

3.3.2. **INTERNAL LAYOUT**

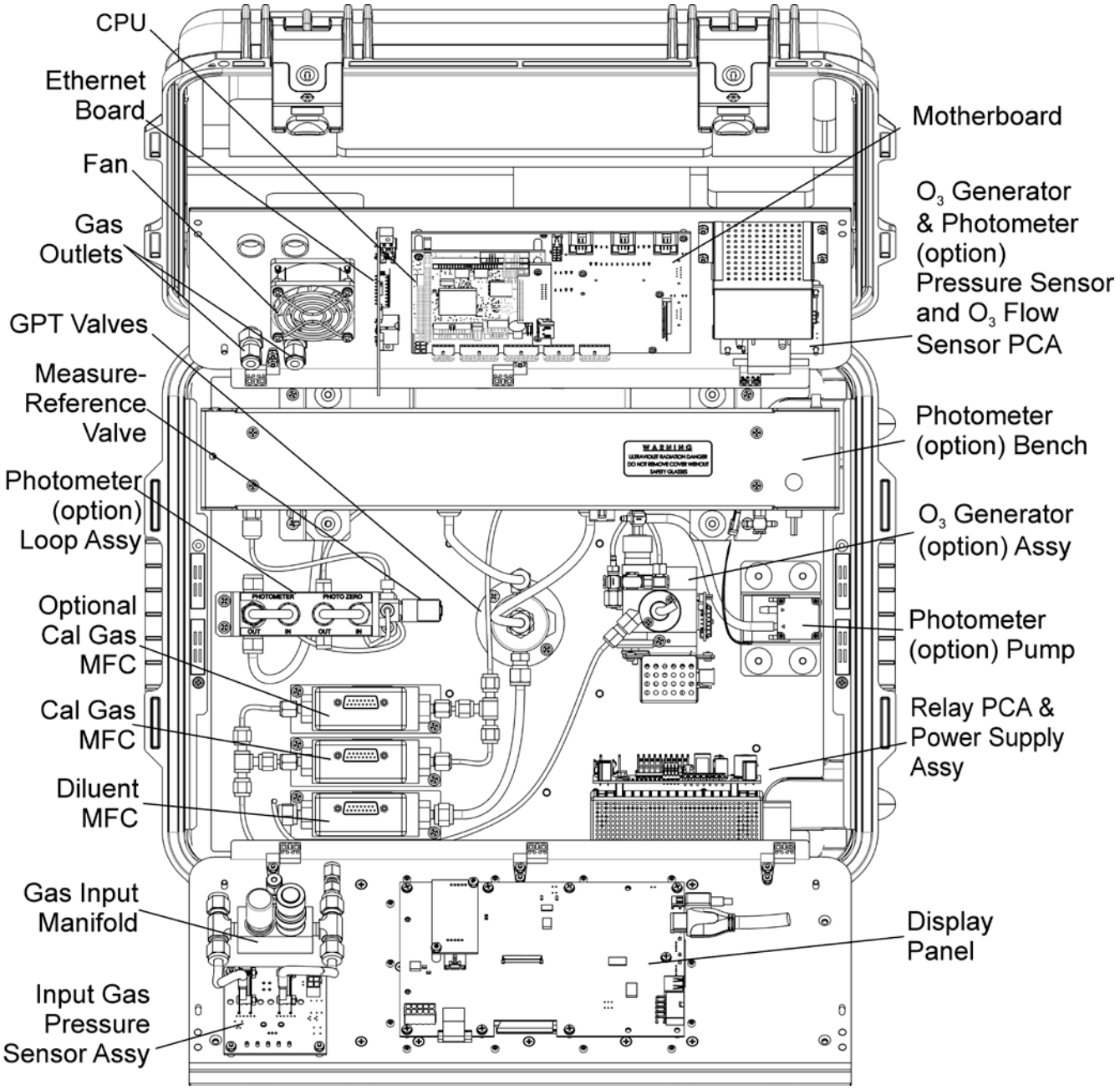


Figure 3-4: T750 Internal Layout

3.4. CONNECTIONS AND SETUP

This section presents the electrical (Section 3.4.1) and pneumatic (Section 3.4.2) connections for setup and preparing for instrument operation.

3.4.1. COMMUNICATIONS AND POWER CONNECTIONS

Figure 3-5 shows the communications and output panel.

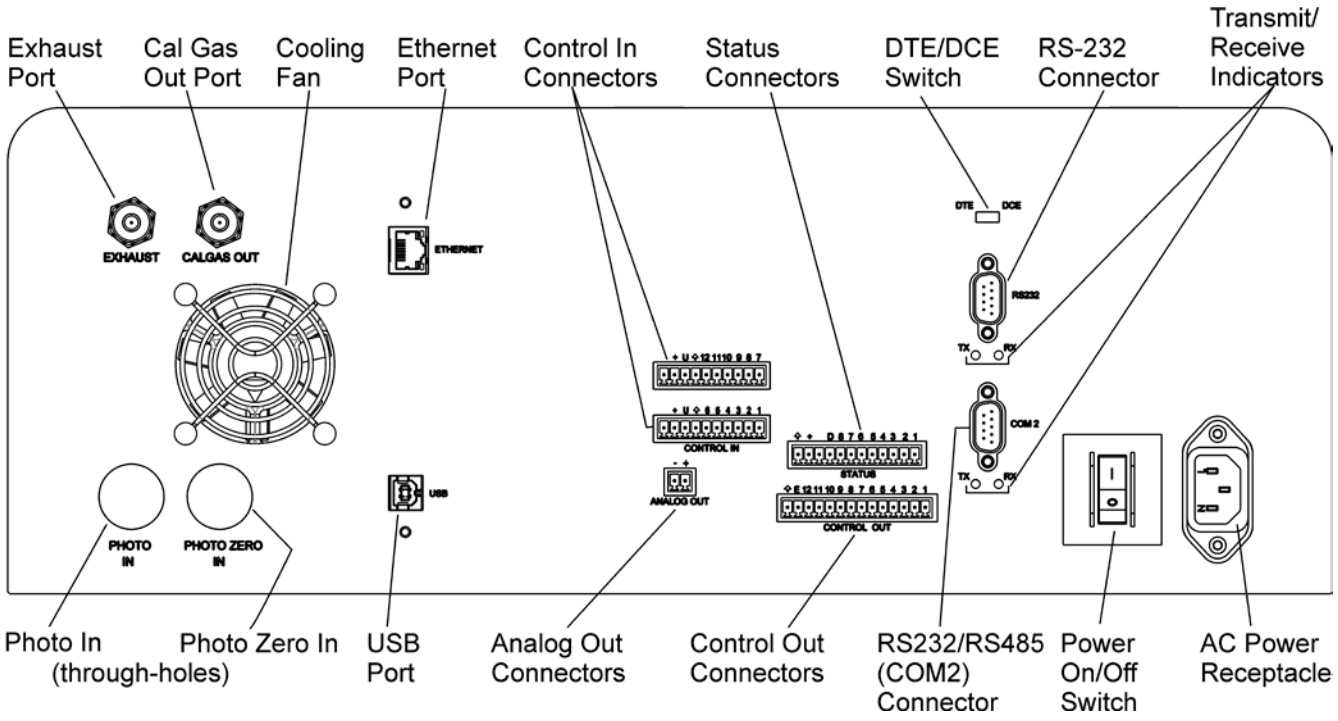


Figure 3-5: Communications and Output Panel

Note **To maintain compliance with EMC standards, it is required that the power cord length be no greater than 3 meters.**

3.4.1.1. Connecting Power

Adhere to the following cautionary messages, and connect the power cord from the AC input connection (AC Power Receptacle in Figure 3-5) to the proper power source.

WARNING – ELECTRICAL SHOCK HAZARD

- **HIGH VOLTAGES ARE PRESENT INSIDE THE CALIBRATOR'S CASE.**
- **POWER CONNECTION MUST HAVE FUNCTIONING GROUND CONNECTION.**
- **ENSURE THAT THE POWER CORD IS PROPERLY GROUNDED AND ADEQUATELY RATED FOR THE POWER RATING OF THIS INSTRUMENT (SEE SPECIFICATIONS TABLE).**
- **TURN OFF CALIBRATOR POWER BEFORE DISCONNECTING OR CONNECTING ELECTRICAL SUBASSEMBLIES.**

CAUTION – AVOID PERSONAL INJURY

DO NOT LOOK AT THE PHOTOMETER UV LAMP; UV LIGHT CAN CAUSE EYE DAMAGE.

ALWAYS WEAR GLASSES MADE FROM SAFETY UV FILTERING GLASS (PLASTIC GLASSES ARE INADEQUATE).

3.4.1.2. Connecting Analog Outputs

The T750 is equipped with an analog output channel accessible through ANALOG OUT connector on the communications and output panel of the instrument. The standard configuration for this output is 0-5 VDC. The user can set this feature to output one of a variety of diagnostic test functions (see Section 4.10.1.2).

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the communications and output panel of the calibrator.

Pin-outs for the analog output connector are:

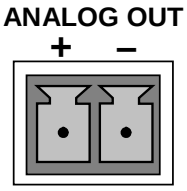


Figure 3-6: T750 Analog Output Connector

3.4.1.3. Connecting the Status Outputs

The status outputs report calibrator conditions via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used to 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.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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

The status outputs are accessed via a 12-pin connector on the calibrator's communications and output panel labeled STATUS. Table 3-2 presents a description of each pin's function.

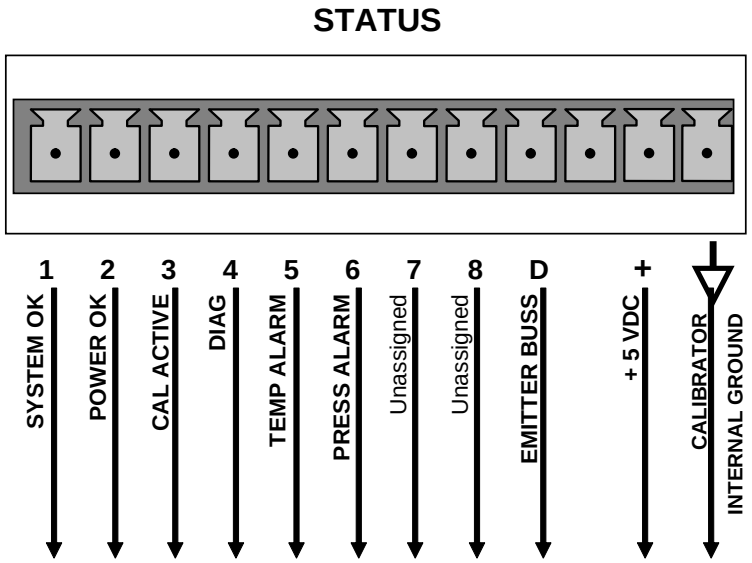


Figure 3-7: Status Output Connector

Table 3-2: Status Output Pin Assignments

OUTPUT #	STATUS DEFINITION	CONDITION
1	SYSTEM OK	On if no faults are present.
2	POWER OK	On if no faults are present.
3	CAL ACTIVE	On if the calibrator is in **GENERATE** mode.
4	DIAG	On if the calibrator is in **DIAGNOSTIC** mode.
5	TEMP ALARM	On while a temperature alarm is active.
6	PRESS ALARM	On while gas pressure alarm is active.
7 & 8	Unassigned	
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
(blank)	(blank)	Not Used
+	DC POWER	+ 5 VDC
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.

3.4.1.4. **Connecting the Control Inputs**

The calibrator is equipped with 12 digital control inputs that can be used to initiate various user programmable calibration sequences (see Section 4.3.1.5 for instructions on assigning the control inputs to specific calibration sequences).

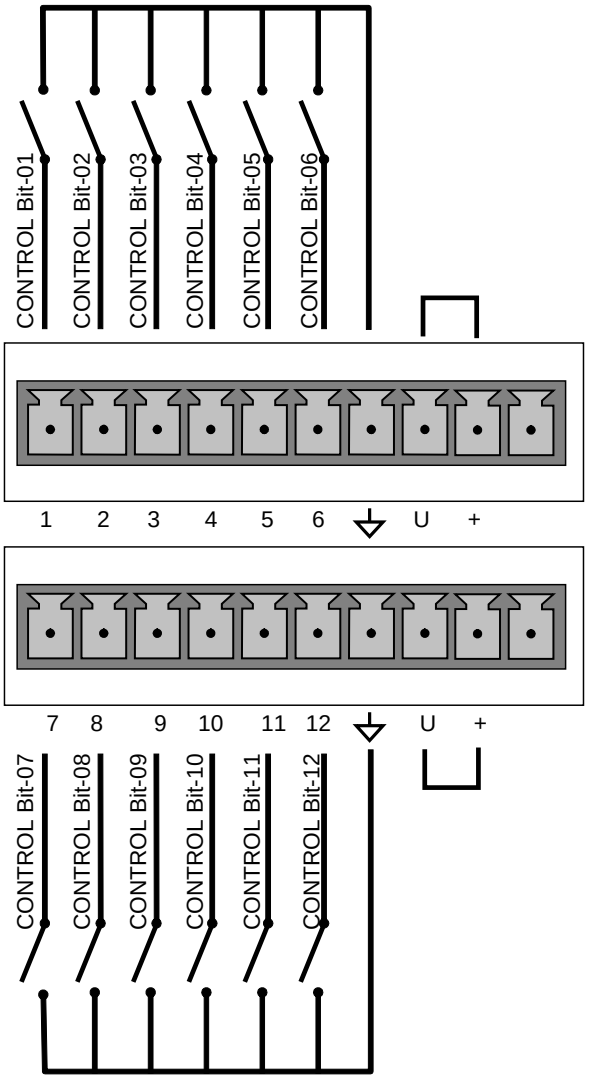
Access to these inputs is via two separate 10-pin connectors, labeled CONTROL IN (Figure 3-8), that are located on the calibrator's communications and output panel.

Table 3-3: T750 Control Input Pin Assignments

CONNECTOR	INPUT	DESCRIPTION
Top	**1 to 6**	Can be used as either 6, separate on/off switches or as bits 1 through 6 of a 12-bit wide binary activation code.
Bottom	**7 to 12**	Can be used as either 6, separate on/off switches or as bits 7 through 12 of a 12-bit wide binary activation code.
BOTH	⏚	Chassis ground.
Top	**U**	Input pin for +5 VDC required to activate pins 1 – 6. This can be from an external source or from the "+" pin of the connector.
Bottom	**U**	Input pin for +5 VDC required to activate pins 7 – 12. This can be from an external source or from the "+" pin of the connector.
BOTH	**+**	Internal source of +5V used to actuate control inputs when connected to the U pin.

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.

Example of Local Power Connections



Example of External Power Connections

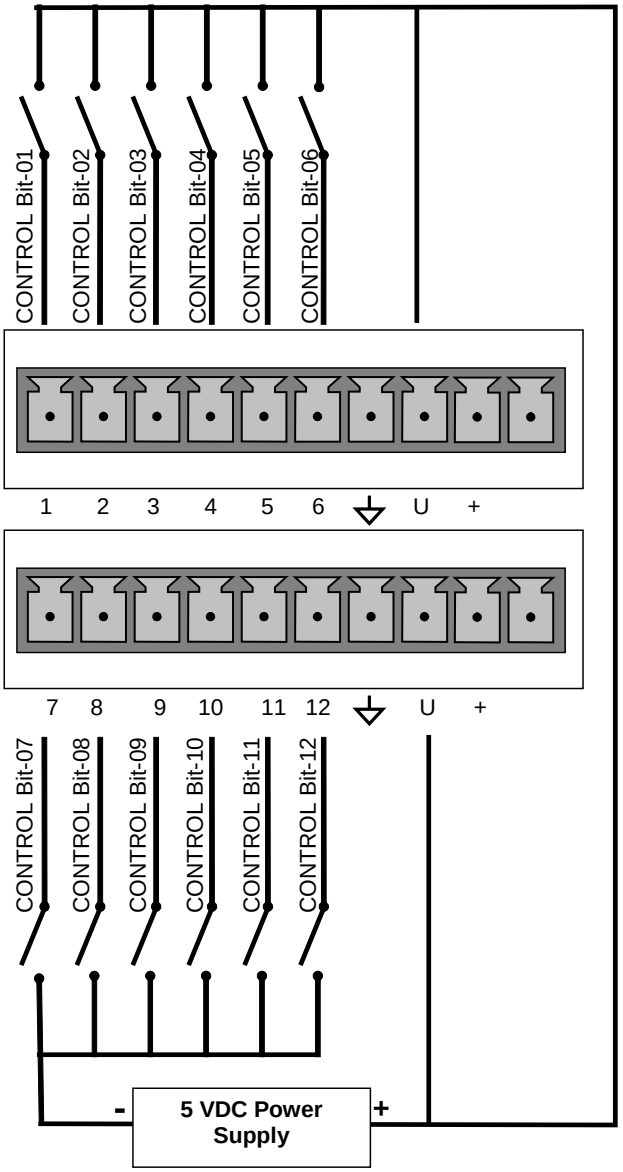


Figure 3-8: T750 Digital Control Input Connectors

3.4.1.5. **Connecting the Control Outputs**

The calibrator is equipped with 12 opto-isolated, digital control outputs. These outputs are activated by the T750's user-programmable calibration sequences (see Sections 4.3.1.6 and 4.3.2.4 for instructions on assigning the control inputs to specific calibration sequences).

These outputs may be used to interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (PLCs), data loggers, or digital relays/valve drivers.

They are accessed via a 14-pin connector (Figure 3-9) on the calibrator's communications and output panel (see Figure 3-5).

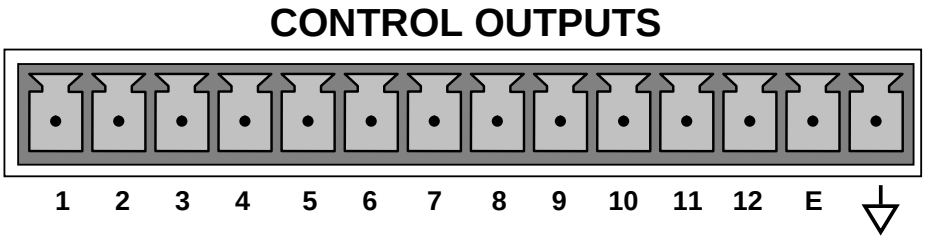


Figure 3-9: T750 Digital Control Output Connector

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Most PLCs have internal provisions for limiting the 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 ≤50mA (120 Ω for 5V supply).

The pin assignments for the control outputs are:

Table 3-4: T750 Control Output Pin Assignments

PIN #	STATUS DEFINITION	CONDITION
1 - 12	Outputs 1 through 12 respectively	Closed if the sequence or sequence step activating output is operating
E	Emitter BUS	The emitters of the transistors on pins 1 to 12 are bussed together.
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.

3.4.1.6. Connecting the Communications Interfaces

The T-Series instruments are equipped with connectors for remote communications interfaces: **Ethernet**, **USB**, **RS-232**, **RS-232 Multidrop** and **RS-485** (each described below). In addition to using the appropriate cables, each type of communication method must be configured using the SETUP>COMM menu (see Sections 4.7 and 5).

ETHERNET CONNECTION

For network or Internet communication with the calibrator, connect an Ethernet cable from the Ethernet interface connector on the calibrator's communications and output panel to an Ethernet port. Although the calibrator is shipped with DHCP enabled by default (Section 5.4), it should be manually assigned a static IP address.

Configuration: (manual, i.e., static) Section 5.4.1.1

USB (OPTION) CONNECTION

The USB option can be used for direct communication between the calibrator and a PC; connect a USB cable between the calibrator and computer USB ports. A USB driver is required for complete configuration.

Note

If this option is installed, the COM2 port cannot be used for anything other than Multidrop communication.

Configuration: Section 5.4.3.

RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A), as applicable, from the communications and output panel RS-232 port to the device. Adjust the DCE-DTE switch (Figure 3-5) to select DTE or DCE as appropriate (Section 5.1).

Configuration: Section 4.7.3

IMPORTANT

IMPACT ON READINGS OR DATA

Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 3-10) before using.

RS-232 COM PORT CONNECTOR PIN-OUTS

Electronically, the difference between the DCE and DTE 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.

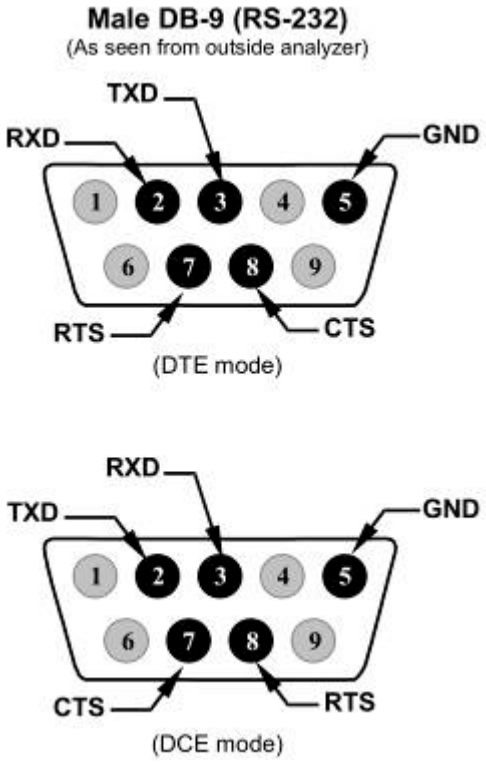


Figure 3-10: Connector Pin-Outs for RS-232 Mode

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 and J12 (Figure 3-11).

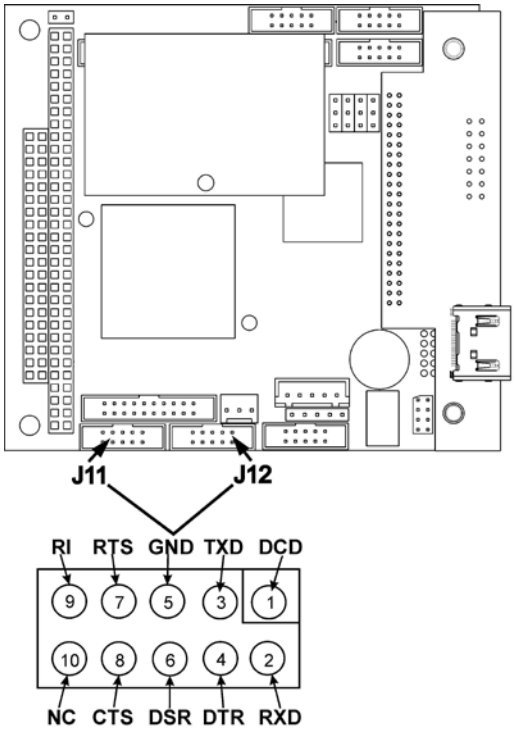


Figure 3-11: Default Pin Assignments for CPU COMM Port Connector (RS-232).

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

- P/N WR000077, a DB-9 female to DB-9 female cable, 6 feet long. Allows connection of the serial ports of most personal computers.
- P/N 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 makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments before using.

To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the calibrator and a computer or modem, both the red and green LEDs should be on.

- If the LEDs are not lit, locate the small switch on the communications and output panel to switch it between DTE and DCE modes.
- If both LEDs are still not illuminated, ensure that the cable properly constructed.

RS-232 COM PORT DEFAULT SETTINGS

Received from the factory, the calibrator 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.

- **RS-232 (COM1)**: 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**: 115200 bits per second (baud)
- **Data Bits**: 8 data bits with 1 stop bit
- **Parity**: None

RS-232 MULTI-DROP (OPTION 62) CONNECTION

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

Because the RS-232 Multidrop option uses both the RS232 and COM2 DB9 connectors on the calibrator's communications and output panel to connect the chain of instruments, COM2 port is no longer available for separate RS-232 or RS-485 operation.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. For information on preventing ESD damage, see *Fundamentals of ESD* manual, PN 04786, available on our website at http://www.teledyne-api.com under Help Center>Product Manuals in the Special Manuals section.

In each instrument with the Multidrop option there is a shunt jumpering two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 3-12. 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, lay the communications and output panel open for access to the Multidrop/LVDS 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. (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 3-12):

   - 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 LCD display and touchscreen panel

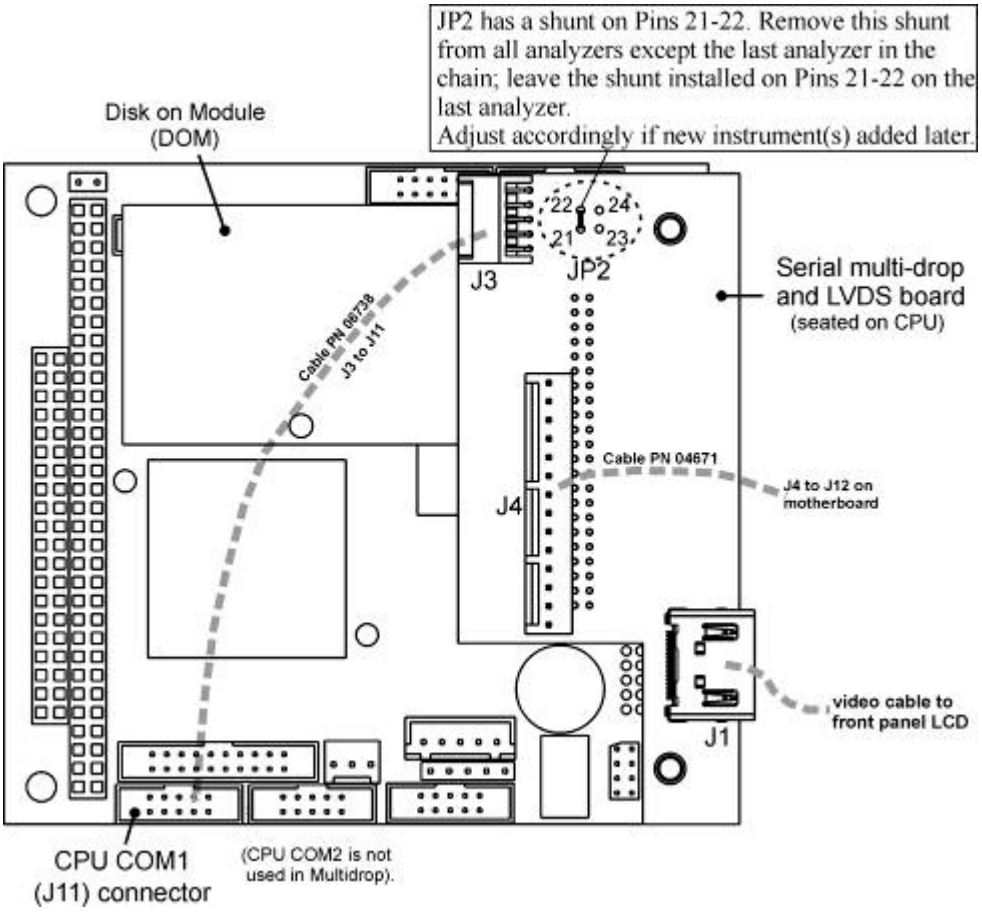


Figure 3-12: Jumper and Cables for Multidrop Mode

(Note: If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 ↔ 22 of JP2 on the Multidrop/LVDS PCA in the instrument that was previously the last instrument in the chain.)

4. Close the instrument.

5. Referring to Figure 3-13 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first calibrator's RS232 port; then from the

first calibrator's COM2 port to the second calibrator's RS232 port; from the second calibrator's COM2 port to the third calibrator's RS232 port, etc., connecting in this fashion up to eight calibrators, subject to the distance limitations of the RS-232 standard.

6. On the communications and output panel of each calibrator, adjust the DCE DTE switch (see Figure 3-5 and Section 5.1) 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 internally wired specifically for RS-232 communication; see Section 3.4.1.6: Connecting the Communications Interfaces, "RS-232 Connection").

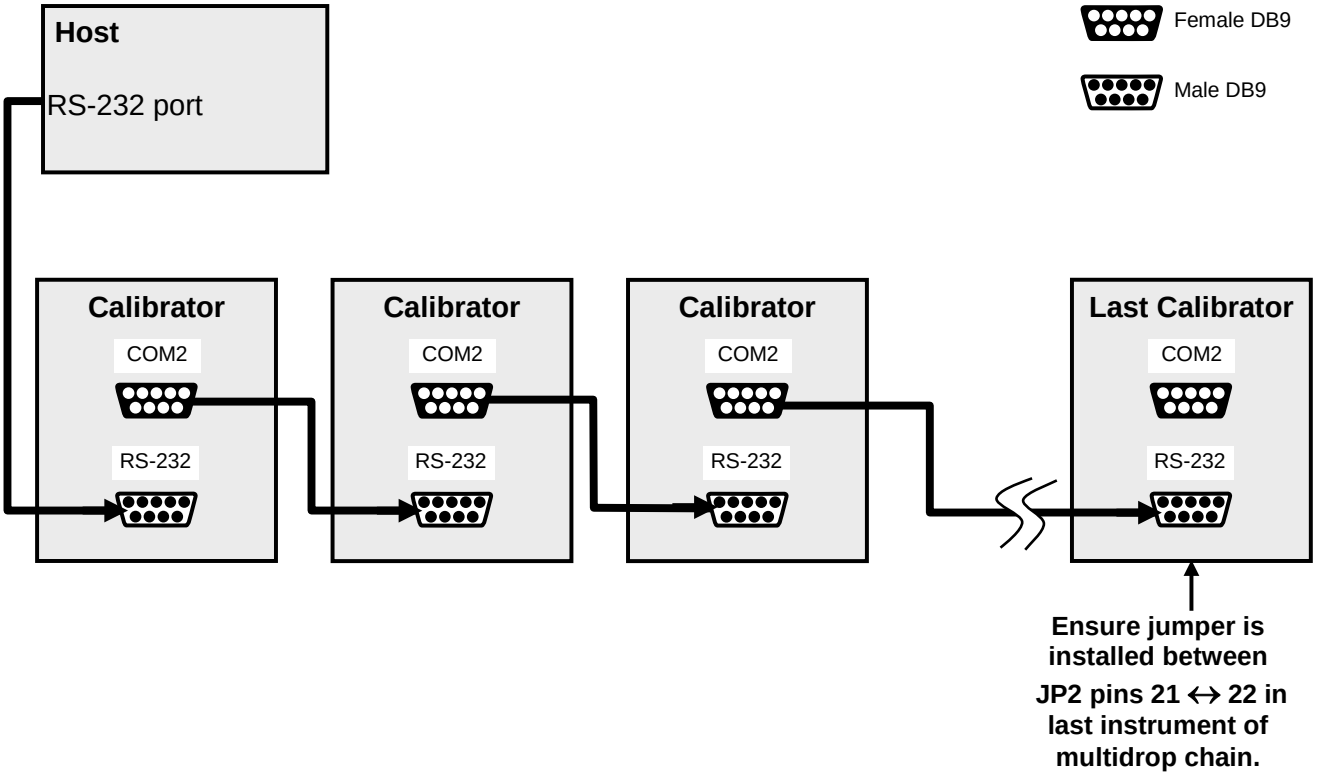


Figure 3-13: RS-232-Multidrop PCA Host/Calibrator Interconnect Diagram

7. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each (Section 4.7.1).

   a. In the SETUP Mode menu go to SETUP>MORE>COMM>ID. The default ID is typically the model number or "0".

   b. to change the identification number, press the button below the digit to be changed.

   c. 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).

Note

The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see step 12 above).

Note

Teledyne API recommends setting up the first link, between the Host and the first calibrator, and testing it before setting up the rest of the chain.

RS-485 CONNECTION

As delivered from the factory, **COM2** is configured for RS-232 communications. This port can be reconfigured for operation as a non-isolated, half-duplex RS-485 port. Using COM2 for RS-485 communication disables the USB port. To reconfigure this port for RS-485 communication, please contact the factory.

3.4.2. PNEUMATIC CONNECTIONS

Note that each time the pneumatic configuration is changed for any purpose, a backpressure compensation calibration must be performed (Section 7.3.7).

3.4.2.1. About Diluent Gas (Zero Air)

Zero Air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the calibrator's readings.

- Diluent Air should be dry (approximately -20ºC of Dew Point).
- Diluent Air should be supplied at a gas pressure of between 25 PSI and 35 PSI with a flow greater than the flow rate for the calibrator. For the standard unit this means greater than 10 SLPM.
    - For calibrators with the 20 LPM diluent flow option (OPT) the diluent air should be supplied at a gas pressure of between 30 PSI and 35 PSI.
- T750 calibrators with optional O_3 generators installed require that the zero air source supply gas flowing at a continuous rate of at least 100 cm^3/min.
    - If the calibrator is also equipped with an internal photometer, the zero air source supply gas must be capable of a continuous rate of flow of at least 1.1 LPM.

Zero Air can be purchased in pressurized canisters or created using a Teledyne API's Model 701 Zero Air Generator.

3.4.2.2. **About Calibration Gas**

Calibration 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. Usually it is a single gas type mixed with N_2 although bottles containing multiple mixtures of compatible gases are also available (e.g. H_2S, O_2 and CO mixed with N_2).

- Calibration gas should be supplied at a pressure of between 25 PSI and 35 PSI with a flow greater than the flow rate for the calibrator.

NIST TRACEABLE CALIBRATION GAS STANDARDS

All calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend acquiring cylinders of working gas that are certified traceable to NIST Standard Reference Materials (SRM). These are available from a variety of commercial sources.

The following tables lists some of the most common NIST Primary gas standards

Table 3-5: NIST Standards for CO_2

SRM	Description	Nominal Amount of Substance
1676	Carbon Dioxide in Air	365 ppm
1674b	Carbon Dioxide in Nitrogen	7 %
1675b	Carbon Dioxide in Nitrogen	14 %
2619a	Carbon Dioxide in Nitrogen	0.5 %
2620a	Carbon Dioxide in Nitrogen	1.0 %
2621a	Carbon Dioxide in Nitrogen	1.5 %
2622a	Carbon Dioxide in Nitrogen	2.0 %
2623a	Carbon Dioxide in Nitrogen	2.5 %
2624a	Carbon Dioxide in Nitrogen	3.0 %
2625a	Carbon Dioxide in Nitrogen	3.5 %
2626a	Carbon Dioxide in Nitrogen	4.0 %
2745	Carbon Dioxide in Nitrogen	16 %

Table 3-6: NIST Standards for CO

SRM	Description	Nominal Amount of Substance
2612a	Carbon Monoxide in Air	10 ppm
2613a	Carbon Monoxide in Air	20 ppm
2614a	Carbon Monoxide in Air	42 ppm
1677c	Carbon Monoxide in Nitrogen	10 ppm
1678c	Carbon Monoxide in Nitrogen	50 ppm
1679c	Carbon Monoxide in Nitrogen	100 ppm
1680b	Carbon Monoxide in Nitrogen	500 ppm
1681b	Carbon Monoxide in Nitrogen	1000 ppm
2635a	Carbon Monoxide in Nitrogen	25 ppm
2636a	Carbon Monoxide in Nitrogen	250 ppm
2637a	Carbon Monoxide in Nitrogen	2500 ppm
2638a	Carbon Monoxide in Nitrogen	5000 ppm
2639a	Carbon Monoxide in Nitrogen	1 %
2640a	Carbon Monoxide in Nitrogen	2 %
2641a	Carbon Monoxide in Nitrogen	4 %
2642a	Carbon Monoxide in Nitrogen	8 %
2740a	Carbon Monoxide in Nitrogen	10 %
2741a	Carbon Monoxide in Nitrogen	13 %

Table 3-7: NIST Standards for H_2S

SRM	Description	Nominal Amount of Substance
2730	Hydrogen Sulfide in Nitrogen	5 ppm
2731	Hydrogen Sulfide in Nitrogen	20 ppm

Table 3-8: NIST Standards for CH_4

SRM	Description	Nominal Amount of Substance
1658a	Methane in Air	1 ppm
1659a	Methane in Air	10 ppm
2750	Methane in Air	50 ppm
2751	Methane in Air	100 ppm
1660a	Methane-Propane in Air	4 : 1

Table 3-9: NIST Standards for O_2

SRM	Description	Nominal Amount of Substance
2657a	Oxygen in Nitrogen	2 %
2658a	Oxygen in Nitrogen	10 %
2659a	Oxygen in Nitrogen	21 %

Table 3-10: NIST Standards for SO_2

SRM	Description	Nominal Amount of substance
1661a	Sulfur Dioxide in Nitrogen	500
1662a	Sulfur Dioxide in Nitrogen	1000 ppm
1663a	Sulfur Dioxide in Nitrogen	1500 ppm
1664a	Sulfur Dioxide in Nitrogen	2500 ppm
1693a	Sulfur Dioxide in Nitrogen	50 ppm
1694a	Sulfur Dioxide in Nitrogen	100 ppm
1696a	Sulfur Dioxide in Nitrogen	3500 ppm

Table 3-11: NIST Standards for NO

SRM	Description	Nominal Amount of Substance
1683b	Nitric Oxide in Nitrogen	50 ppm
1684b	Nitric Oxide in Nitrogen	100 ppm
1685b	Nitric Oxide in Nitrogen	250 ppm
1686b	Nitric Oxide in Nitrogen	500 ppm
1687b	Nitric Oxide in Nitrogen	1000 ppm
2627a	Nitric Oxide in Nitrogen	5 ppm
2628a	Nitric Oxide in Nitrogen	10 ppm
2629a	Nitric Oxide in Nitrogen	20 ppm
2630	Nitric Oxide in Nitrogen	1500 ppm
2631a	Nitric Oxide in Nitrogen	3000 ppm
2735	Nitric Oxide in Nitrogen	800 ppm
2736a	Nitric Oxide in Nitrogen	2000 ppm
2737	Nitric Oxide in Nitrogen	500 ppm
2738	Nitric Oxide in Nitrogen	1000 ppm

Table 3-12: NIST Standards for Propane (C_3H_8)

SRM	Description	Nominal Amount of Substance
1665b	Propane in Air	3 ppm
1666b	Propane in Air	10 ppm
1667b	Propane in Air	50 ppm
1668b	Propane in Air	100 ppm
1669b	Propane in Air	500 ppm
2764	Propane in Air	0.25 ppm
2644a	Propane in Nitrogen	250 ppm
2646a	Propane in Nitrogen	1000 ppm
2647a	Propane in Nitrogen	2500 ppm
2648a	Propane in Nitrogen	5000 ppm

MINIMUM CALIBRATION GAS SOURCE CONCENTRATION

Determining minimum Cal Gas Concentration to determine the minimum concentration of a calibration gas required by your system:

1. Determine the Total Flow required by your system by adding the gas flow requirement of each of the analyzers in the system.
2. Multiply this by 1.5.
3. Decide on a Calibration Gas flow rate.
4. Determine the Calibration Gas ratio by divide the Total Flow by the Calibration Gas Flow Rate.
5. Multiply the desired target calibration gas concentration by the result from step 4.

   EXAMPLE: Your system has two analyzers each requiring 2SLPM of cal gas flow.

   2SLPM + 2SLPM = 4SLPM

   4SLPM x 1.5 = 6SLPM = Total Gas Flow Rate

   If the T750 calibrator is configured so that the cal gas flow rate is 2SLPM (therefore the Diluent Flow Rate would need to be set at 4 SLPM) the Calibration Gas ratio would be:

   6SLPMm ÷ 2SLPM = 3:1

   Therefore if your Target Calibration Gas Concentration is intended to be 200 ppm, the minimum required source gas concentration for this system operating at these flow rates would be:

   3 x 200ppm = 600 ppm

3.4.2.3. **Connecting Diluent Gas to the Calibrator**

1 Attach the zero air source line to the port labeled Diluent In.

2 Use the fittings provided with the calibrator to connect the zero air source line.
- First, finger tighten.
- Then using the properly sized wrench, make an additional 1 and ¼ turn.

3.4.2.4. **Connecting Calibration Source Gas to the T750 Calibrator**

Connect the source gas line to the CYL IN port (see Figure 3-1).
- Source gas delivery pressure should be regulated between 25 PSI to 30 PSI.
- Use stainless steel tubing with a 1/8 inch outer diameter.

3.4.2.5. **Connecting Gas Outputs from the Calibrator**

SET UP FOR DIRECT CONNECTIONS TO OTHER INSTRUMENTS

Use this setup if you are connecting the T750 calibrator directly to other instruments without the use of any shared manifolds.

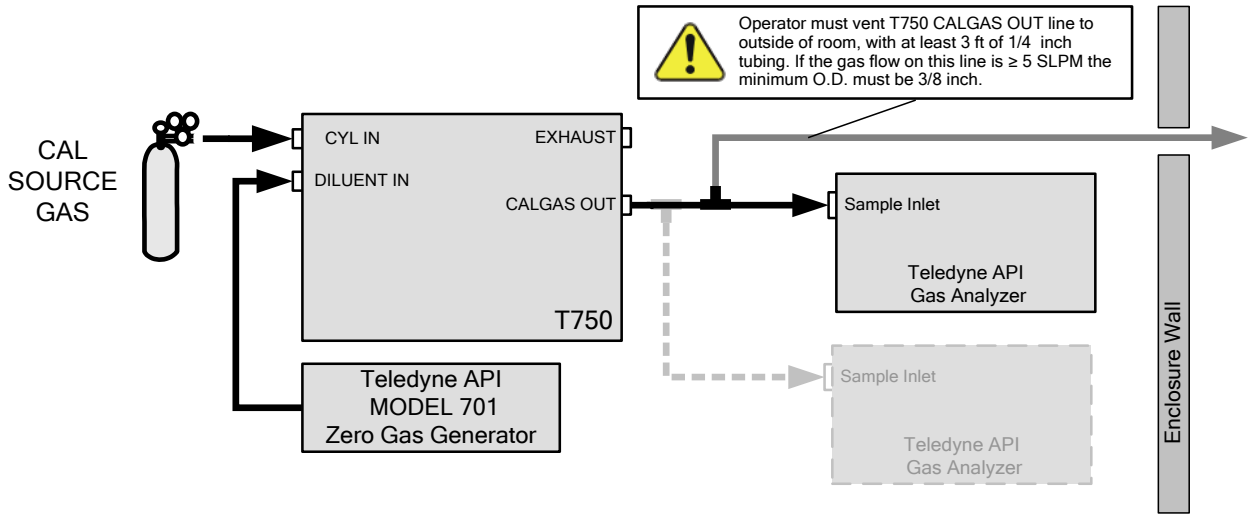


Figure 3-14: Set up for T750 – Connecting the Basic T750 to a Sample Manifold

To determine if the gas flow on the vent line is ≥ 5 SLPM, subtract the gas flow for each instrument connected to the outlets of the T750 from the TOTAL FLOW setting for the calibrator (see Section 3.5.9).

If the T750 has the optional O3 photometer installed, remember that this option requires 800 cc3/min (0.8 LPM) of additional flow (see Section 3.5.9 or Figure 3-20).

EXAMPLE: Your system has two analyzers each requiring 2SLPM of cal gas flow and the T750 includes the O_3 photometer. If the TOTAL FLOW rate for the calibrator is set at 10 SLPM:

10LPM - 2LPM - 2LPM - 0.8 LPM = 5.2LPM

Therefore, the vent would require a gas line with an O.D. 3/8 inch.

CONNECTING THE CALIBRATOR TO A SAMPLE GAS MANIFOLD

Use this setup when connecting the T750 calibrator to an analyzer network using a sample manifold. In this case, the sampling cane and the manifold itself act as the vent for the T750.

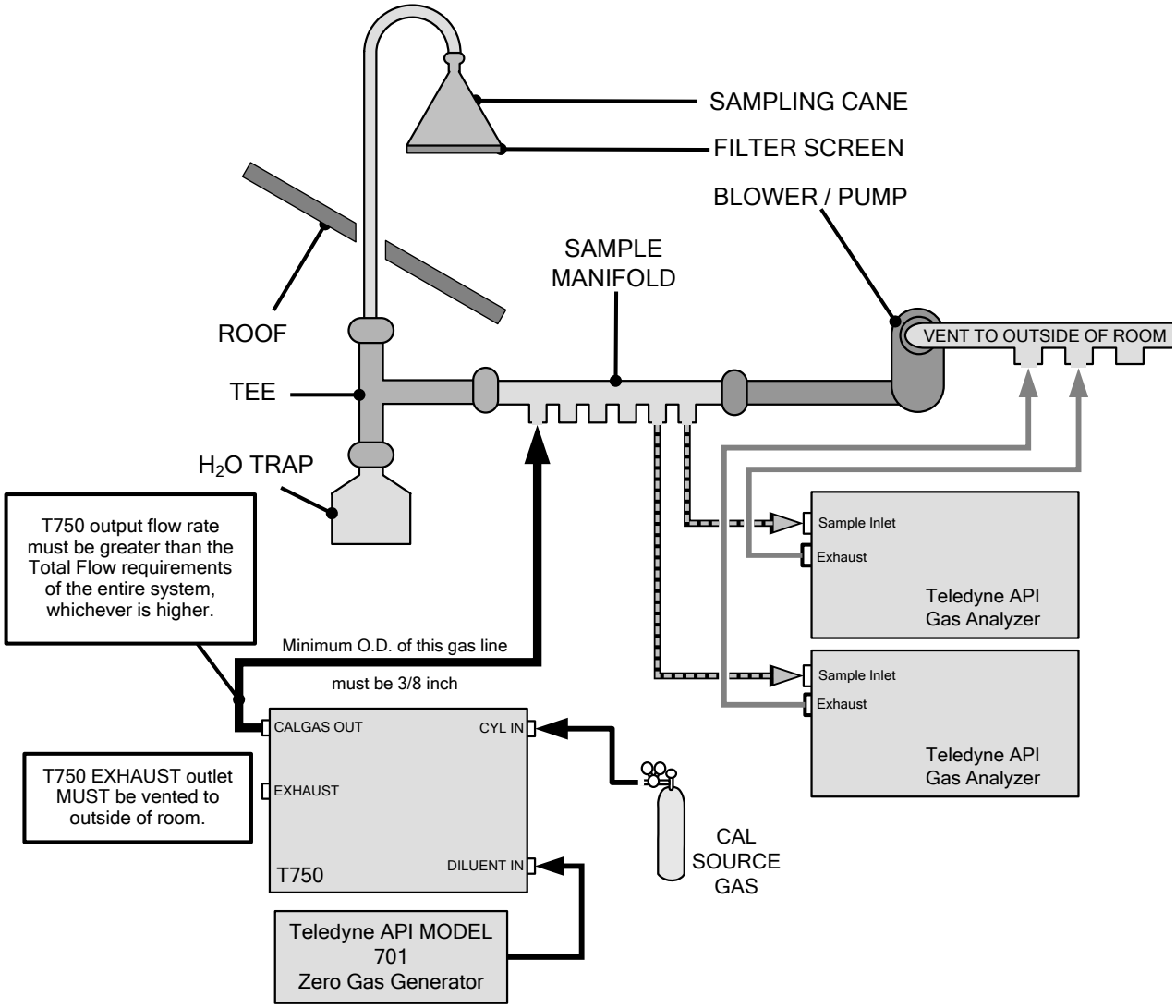


Figure 3-15: Set up for T750 – Connecting the T750 to a Sample Manifold

Note

- **This is the recommended method for connecting the T750 calibrator to a system with analyzers that DO NOT have internal zero/span valves.**
- **The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.**
- **When initiating calibration, wait a minimum of 15 minutes for the calibrator to flood the entire sampling system with calibration gas.**

CONNECTING THE CALIBRATOR TO A CALIBRATION MANIFOLD

Using a calibration manifold provides a pneumatic interface between the calibration system and other devices (or systems) which use the calibrator's gas output. Calibration manifolds usually have one or more ports for connections to other external devices (such as an analyzer).

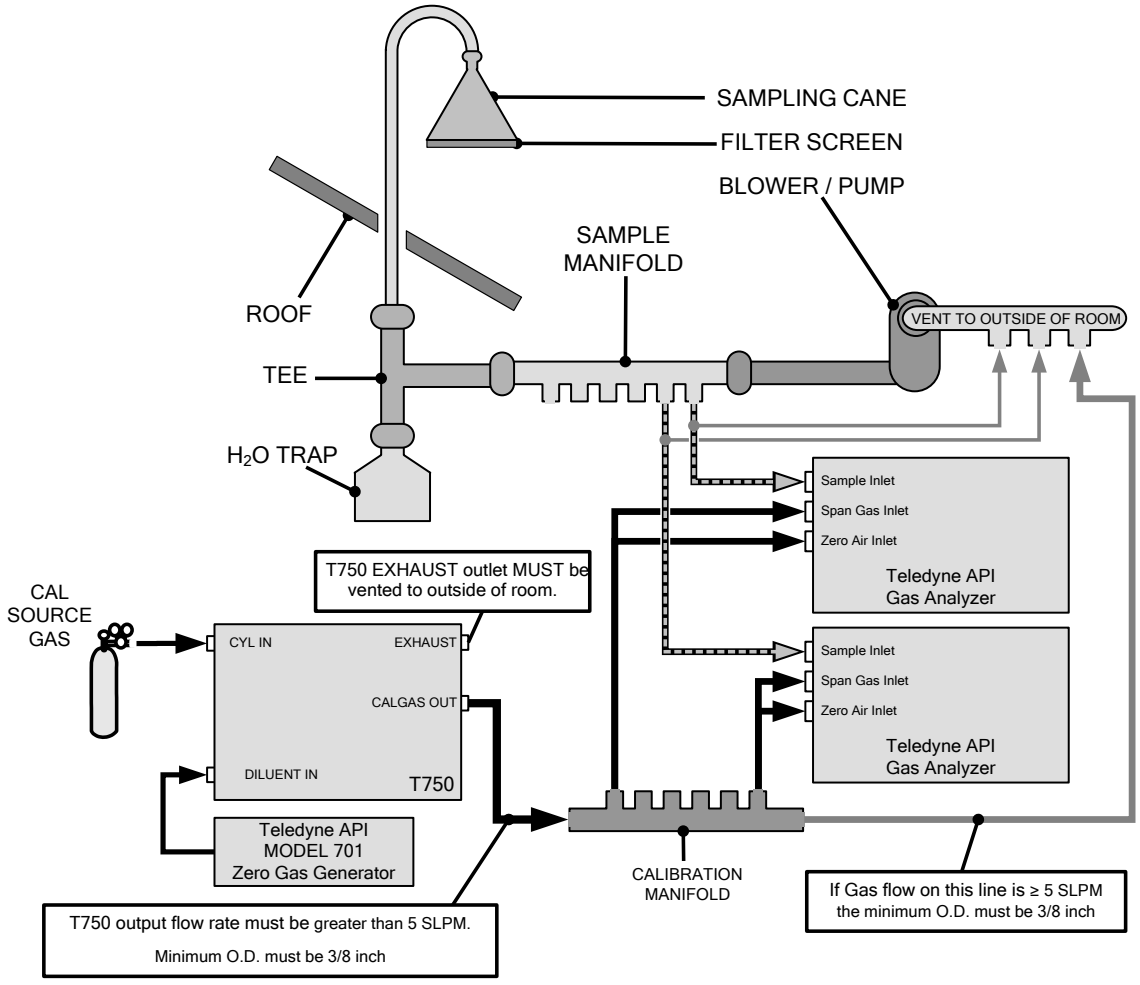


Figure 3-16: Set up for T750 – Connecting the T750 to a Calibration Manifold

Note

- **This method requires the analyzers connected to the calibration system have internal zero/span valves.**
- **The manifold should be kept as clean as possible to avoid loss of sample gas flow from blockages or constrictions.**
- **The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.**
- **When initiating calibration, wait a minimum of 15 minutes for the calibrator to flood the entire calibration manifold with calibration gas.**

CALIBRATION MANIFOLD EXHAUST/VENT LINE

The manifold's excess gas should be vented outside of the room. This vent should be of large enough internal diameter to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to assure that no ambient air enters the manifold due to eddy currents or back diffusion.

CONNECTING THE CALIBRATOR TO A DUAL SPAN GAS / ZERO AIR CALIBRATION MANIFOLD

Another type of calibration setup utilizes separate span gas and the zero air manifolds (see Figure 3-17).

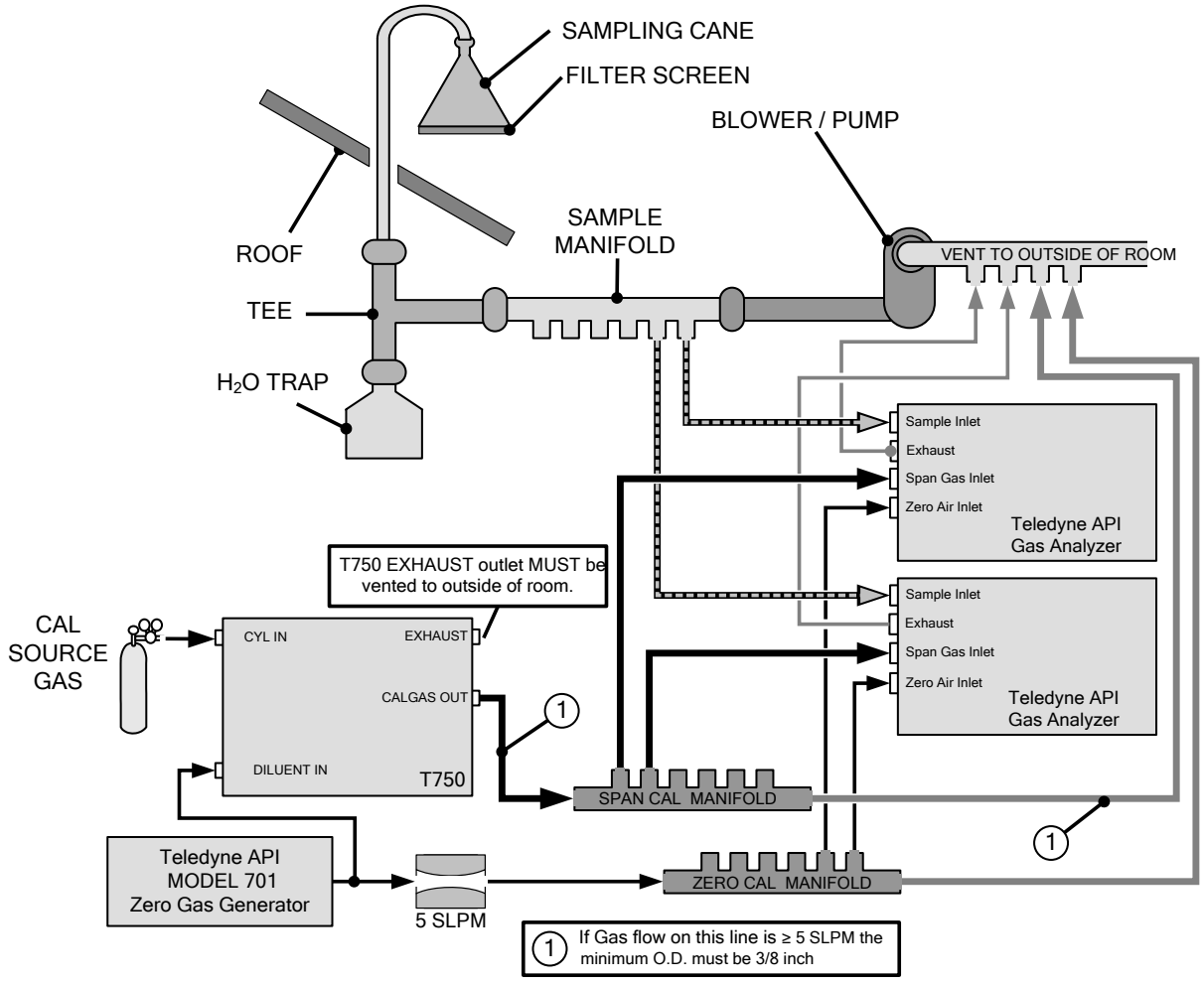


Figure 3-17: Set up for T750 – Connecting the T750 to a Dual Span Gas / Zero Air Manifold

Note

This set up is subject to the same notes and conditions as the single calibration manifold described previously with the following two exceptions:

• The T750 total gas flow rate (Cal Gas Flow Rate + Diluent Flow Rate) out should be greater than the Total Flow requirements of the entire system.

• The manifolds as shown in the above drawing are oriented to simplify the drawing. Their actual orientation in your set-up is with the ports facing upward. All unused ports must be capped.

SPAN GAS/ZERO AIR CALIBRATION MANIFOLD EXHAUST/VENT LINES

The span and zero air manifolds' excess gas should be vented to a suitable vent outside of the room. This vent should be of large enough internal diameter to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to assure that no ambient air enters the manifold due to eddy currents or back diffusion.

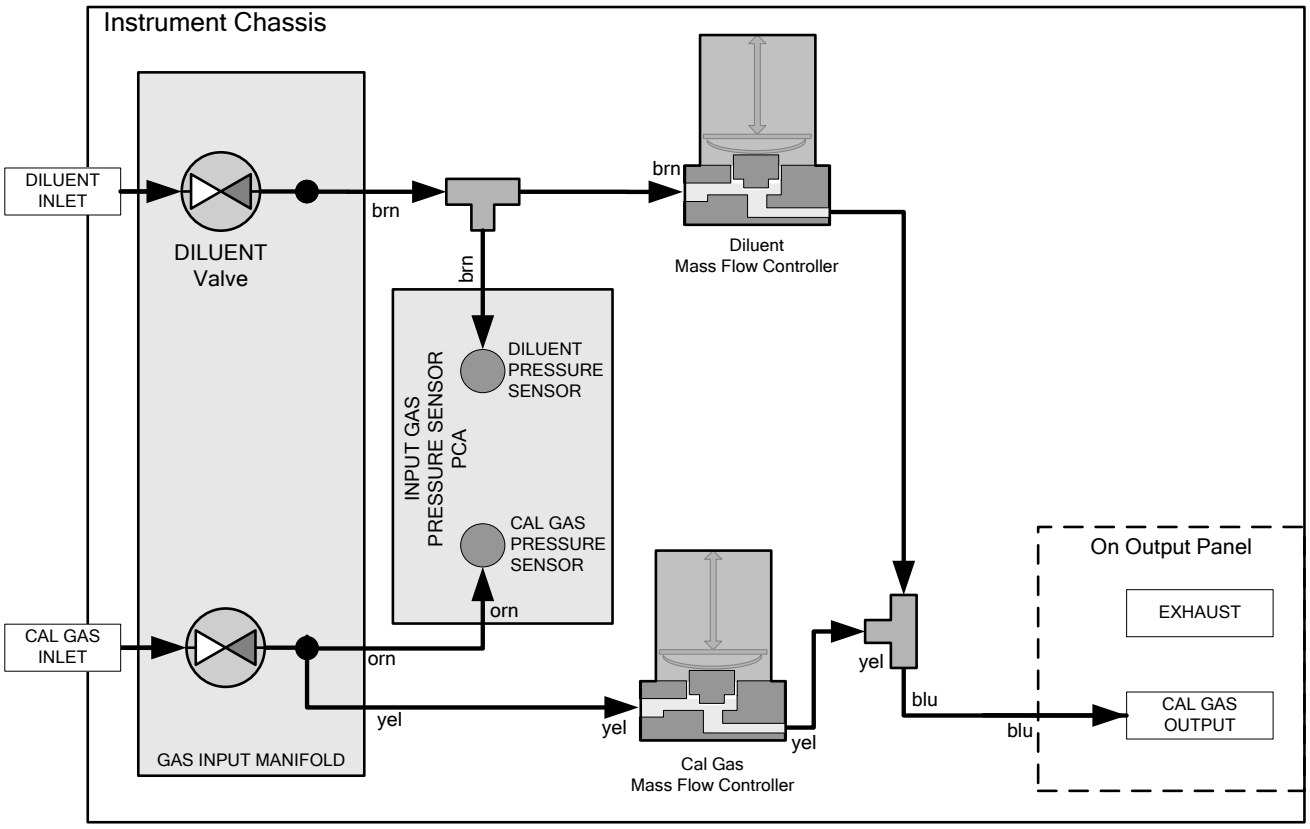


Figure 3-18: T750 Pneumatic Diagram – Base Unit

The standard T750 Portable Calibrator is equipped with one calibration gas mass flow controller (flow rate 0 – 100 cm^3/min) and one diluent gas mass flow controller (flow rate 0-10 LPM).

3.4.2.6. Other Pneumatic Connections

Some of the T750 Portable Calibrator's optional equipment requires additional pneumatic connections.

O_3 GENERATOR OPTION

Because ozone (O_3) quickly breaks down into molecular oxygen (O_2), this calibration gas cannot be supplied in precisely calibrated bottles like other gases such as SO_2, CO, CO_2 NO, H_2S, etc. The optional O_3 generator extends the capabilities of the T750 Portable Calibrator to dynamically generate calibration gas mixtures containing O_3.

Additionally a glass mixture volume, designed to meet US EPA guidelines for Gas Phase Titration (GPT), is included with this option. This chamber, in combination with

the O_3 generator, allows the T750 to use the GPT technique to more precisely create NO_2 calibration mixtures.

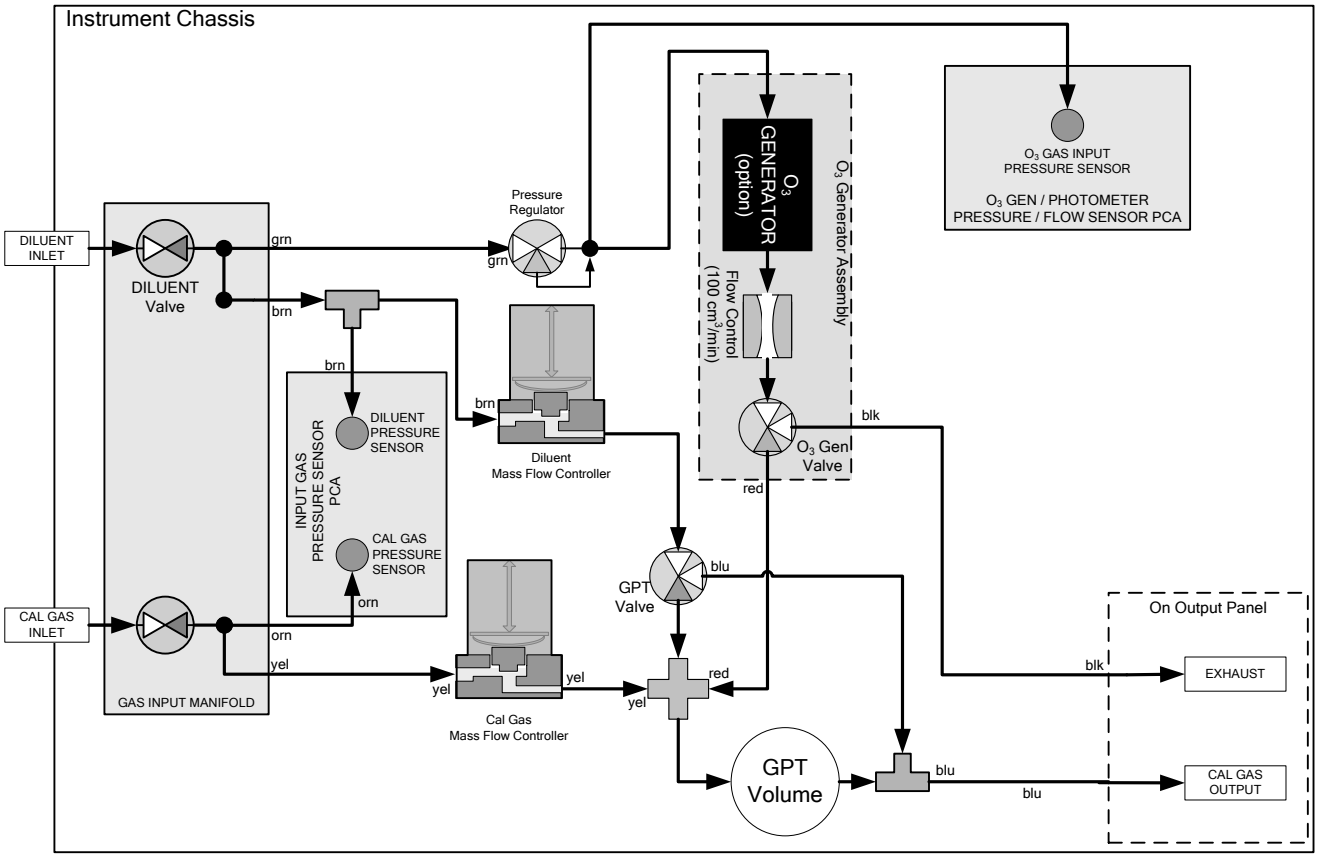


Figure 3-19: T750 Pneumatics with Optional O_3 Generator and GPT Chamber

Table 3-13: Valve States for T750 Calibrator with Optional O_3 Generator.

MODE	VALVES (X = Closed; O = Open) D = Degenerized; E = Energized				MFCs		
	CYL IN	DILUENT IN	GPT	O_3 GEN	CAL1	CAL2[1]	DILUENT
Generate Source Gas	O[2]	O	D	D	ON[3]	ON[3]	ON
Generate O_3	X	O	D	E	OFF	OFF	OFF
Leak Check 0-17%	X	O	D	D	ON	ON	ON
Leak Check 17%-100%	X	X	D	D	ON	ON	ON
GPT	O[2]	O	E	E	ON[3]	ON[3]	ON
GPTZ	O	O	E	E	ON	ON	ON
GPTPS	X	O	D	E	OFF	OFF	ON
STANDBY	X	O	D	D	OFF	OFF	OFF

[1] Only present if multiple cal gas MFC option is installed.

[2] The valve associated with the cylinder containing the chosen source gas is open.

[3] In instruments with multiple MFCs, the CPU chooses which MFC to use depending on the target gas flow requested.

The output of the O_3 generator can be controlled in either of two ways:

- CONSTANT mode: By selecting a specific, constant drive voltage (corresponding to a specific O_3 concentration) for the generator, or;
- BENCH mode: The user selects a desired O_3 concentration, and the calibrator's CPU sets the intensity of the O_3 generator's UV lamp to a drive voltage corresponding to that concentration.

See Section 10.6 for more details on the operation of the O_3 generator.

In addition to the diluent gas, calibration source gas, and gas output connections discussed in the preceding sections, this option also requires an O_3 exhaust line be connected to the EXHAUST outlet on the output panel of the T750 (see Figure 3-5).

Note

The EXHAUST line must be vented to atmospheric pressure using maximum of 10 meters of ¼" PTFE tubing.

Venting must be outside the shelter or immediate area surrounding the instrument.

O_3 GENERATOR WITH PHOTOMETER OPTION

The photometer option increases the accuracy of the T750 calibrator's optional O_3 generator (OPT 1A) by directly measuring O_3 content of the gas output by the generator.

The photometer's operation is based on the principle that ozone molecules absorb UV light of a certain wavelength. A mercury lamp internal to the photometer emits UV light at that wavelength. This light shines down a hollow glass tube that is alternately filled with sample gas (the measure phase), and zero gas (the reference phase). A detector, located at the other end of the glass tube measures the brightness of the UV light after it

passes though the gas in the tube. The O_3 content of the gas is calculated based on the ratio the UV light intensity during the measure phase (O_3 present) and the reference phase (no O_3 present).

When the photometer option is installed, a third more precise and stabile option, called the BENCH feedback mode, exists for controlling the output of the O_3 generator. In BENCH mode the intensity of the O_3 generator's UV lamp is controlled (and therefore the concentration of the O_3 created) by the T750's CPU based on the actual O_3 concentration measurements made by the photometer.

See Section 10.7 for more details on the operation of the O_3 photometer.

This option requires that the O_3 generator (OPT 1A) be installed.

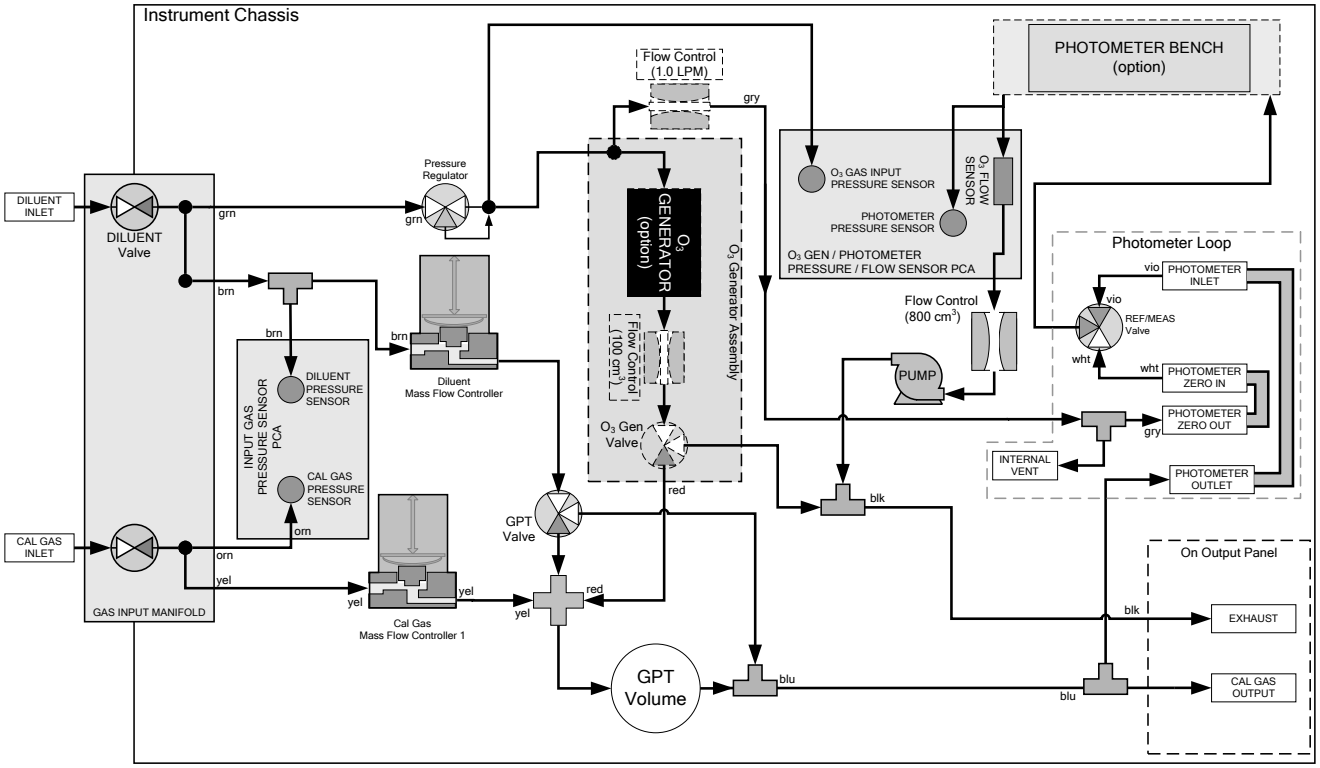


Figure 3-20: Internal Pneumatics for T750 Calibrator with Optional O_3 Generator and Photometer

Table 3-14: Valve States for T750 with Optional O_3 Generator and Photometer

GAS TYPE	VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized)					MFCs			PHOT PUMP
	CYL IN	DILUENT IN	GPT	O_3 GEN	PHOT M/R	CAL	CAL2[1]	DILUENT	
Generate Source Gas	**O**	**O**	**D**	**D**	Reference Phase	**ON**[3]	**ON**[2]	**ON**	**OFF**
Generate O_3	**X**	**O**	**D**	**E**	Switching	**OFF**	**OFF**	**OFF**	**ON**[3]
Leak Check 0-17%	**X**	**O**	**D**	**D**		**ON**	**ON**	**ON**	
Leak Check 17%-100%	**X**	**X**	**D**	**D**		**ON**	**ON**	**ON**	
GPT	**O**	**O**	**E**	**E**	Reference Phase	**ON**[2]	**ON**[2]	**ON**	**OFF**
GPTZ	**O**	**O**	**E**	**E**	Reference Phase	**ON**	**ON**	**ON**	**OFF**
GPTPS	**X**	**O**	**D**	**E**	Switching	**OFF**	**OFF**	**ON**	**ON**[3]
STANDBY	**X**	**O**	**D**	**D**	Reference Phase	**OFF**	**OFF**	**OFF**	**OFF**

[1] Only present if multiple cal gas MFC option is installed.

[2] In an instrument with multiple MFCs the CPU chooses which MFC to use depending on the target gas flow requested.

[3] When generating O_3 or in GPT Pre-Set mode, the photometer pump is the primary creator of gas flow through the T750. Flow rates are controlled by critical flow orifice(s) located in the gas stream

In addition to the connections discussed in the previous sections, this option also requires the following:

- Loop back lines must be connected between:
  - PHOTOMETER OUTLET fixture and the PHOTOMETER INLET fixture.
  - PHOTOMETER ZERO OUT fixture and the PHOTOMETER ZERO IN fixture.
- An O_3 exhaust line must be connected to the **EXHAUST** outlet.

See Figure 3-4 for the location of these fixtures.

Note

The EXHAUST line must be vented to atmospheric pressure using maximum of 10 meters of ¼" PTFE tubing. This venting must be outside the shelter or immediate area surrounding the instrument.

MULTIPLE CALIBRATION SOURCE GAS MFC'S

An optional third mass flow controller can be added on the calibration gas stream. When this option is installed, the T750 has both calibration gas MFCs on the same gas stream, installed in parallel (see Figure 3-21 and Figure 3-22). The calibrator turns on the MFC with the lowest flow rate that can accommodate the requested flow and can therefore supply the most accurate flow control. When a flow rate is requested that is higher than the highest rated MFC (but lower than their combined maximum flow rating), both controllers are activated.

EXAMPLE:

- Calibrator with one calibration gas MFC configured for 0-5 LPM:
  Maximum gas flow = 5 LPM
  Minimum gas flow = 500 cm^3/min
- Calibrator with two calibration gas MFCs configured for 0-1 LPM and 0-5 LPM:

Calibration gas flow rates:

5.001 to 6.000 LPM; both MFCs active
1.001 LPM – 5.000 LPM; High MFC active;
0.100 LPM – 1.000 LPM; Low MFC active

When this option is installed the test measurements that show the MFC actual and target flows (e.g., **ACT CAL**; **TARG CAL**) show the sum of the flows of all the active MFCs. On the other hand, the pressure test measurements show the pressure for only one MFC, not the sum as it is assumed that gas pressure is the same for all MFCs.

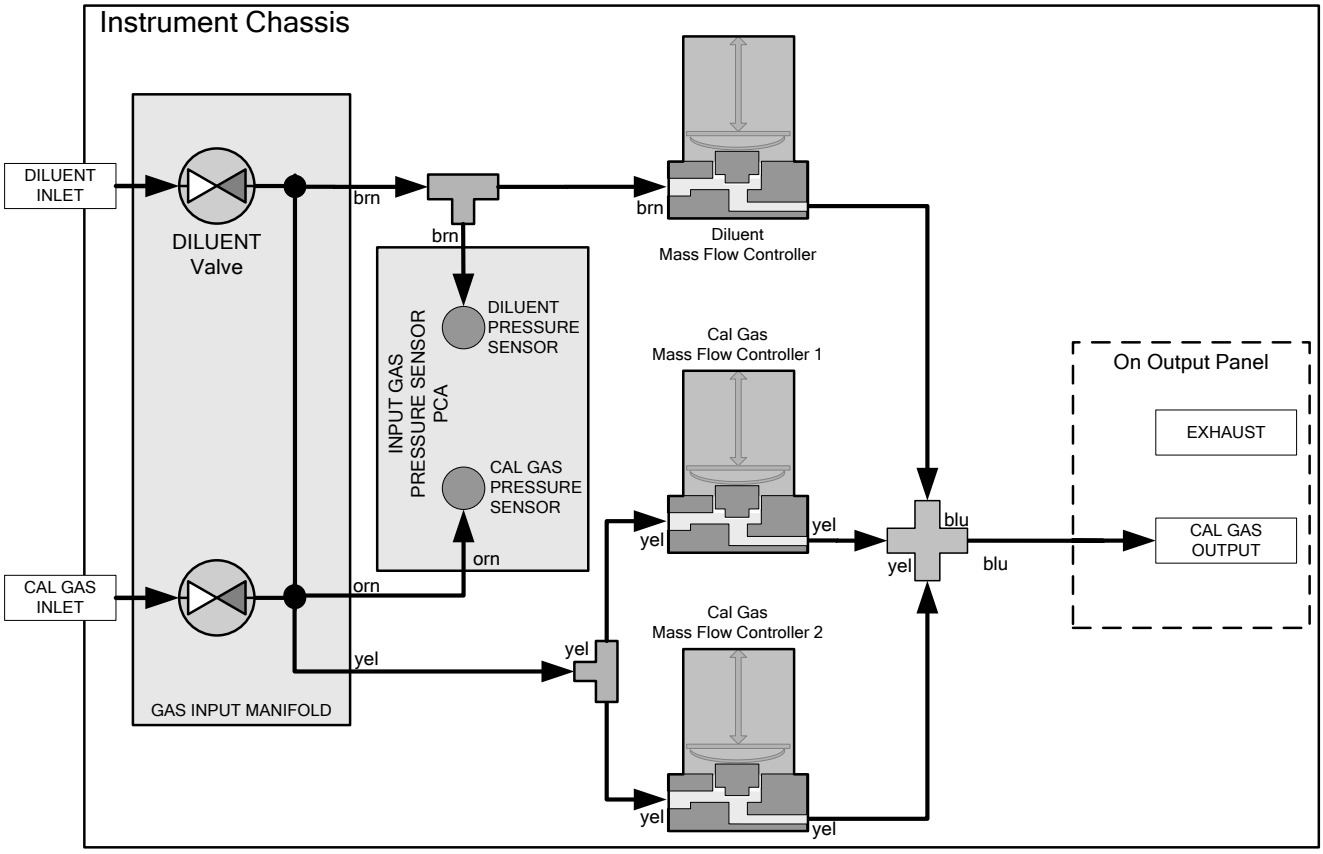


Figure 3-21: Basic T750 with Multiple Calibration Gas MFCs

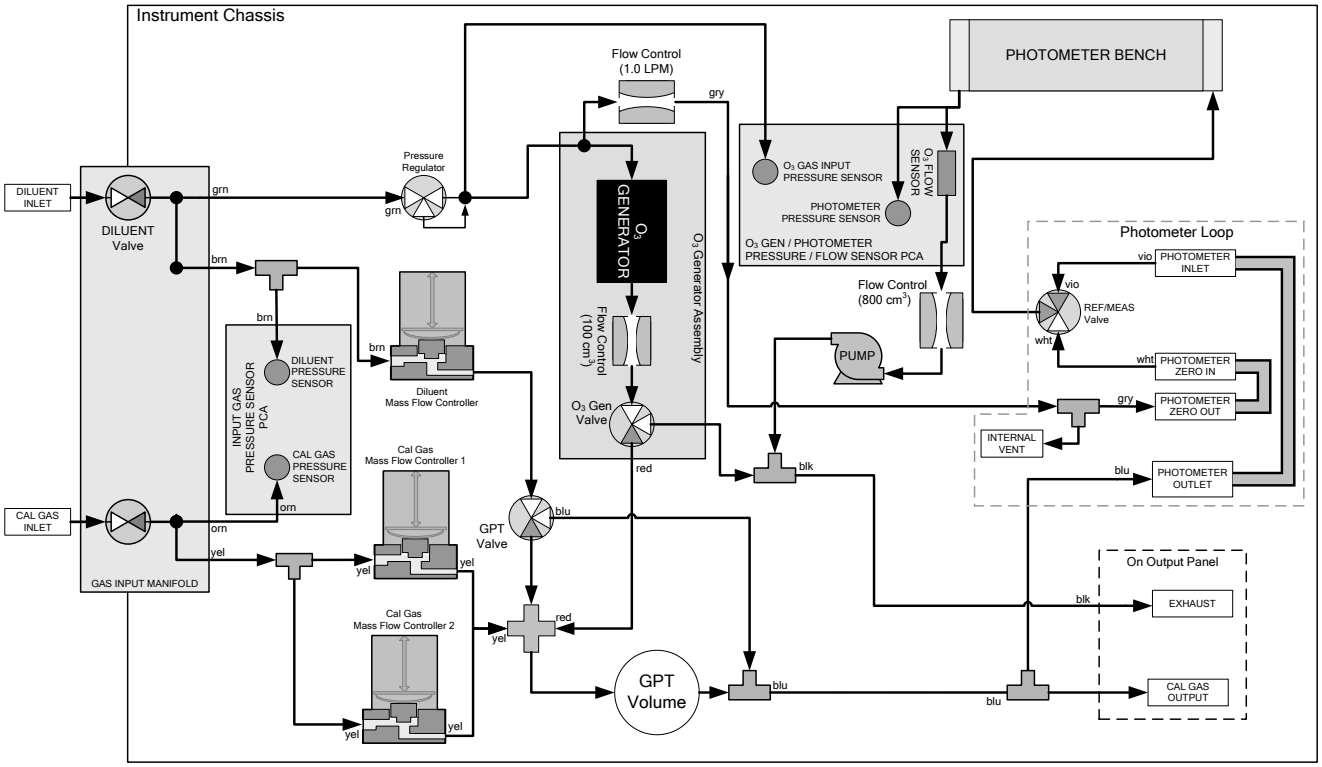


Figure 3-22: T750 with Multiple Calibration Gas MFCs and O_3 Generator and Photometer Options

3.5. STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION

If you are unfamiliar with the T750 principles of operation, we recommend that you read Section 10.

For information on navigating the calibrator's software menus, see the menu trees described in Appendix A.

3.5.1. START UP

After the communications and pneumatic connections are made, an initial functional check is in order. Turn on the instrument. The exhaust fan (and pump if photometer option installed) should start immediately. The LCD touchscreen will show a splash screen and other information during the initialization process while the CPU loads the operating system, the firmware and the configuration data.

The calibrator should automatically switch to STANDBY mode after completing the brief boot-up sequence. However, it the T750 Portable Calibrator requires a minimum of 30 minutes for all of its internal components to reach a stable operating temperature. During the warm-up period, the LCD touchscreen may show messages in the Parameters field.

3.5.2. **WARNING MESSAGES**

Because internal temperatures and other conditions may be outside be specified limits during the calibrator's warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 30 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 9 of this manual.

To view and clear warning messages, press:

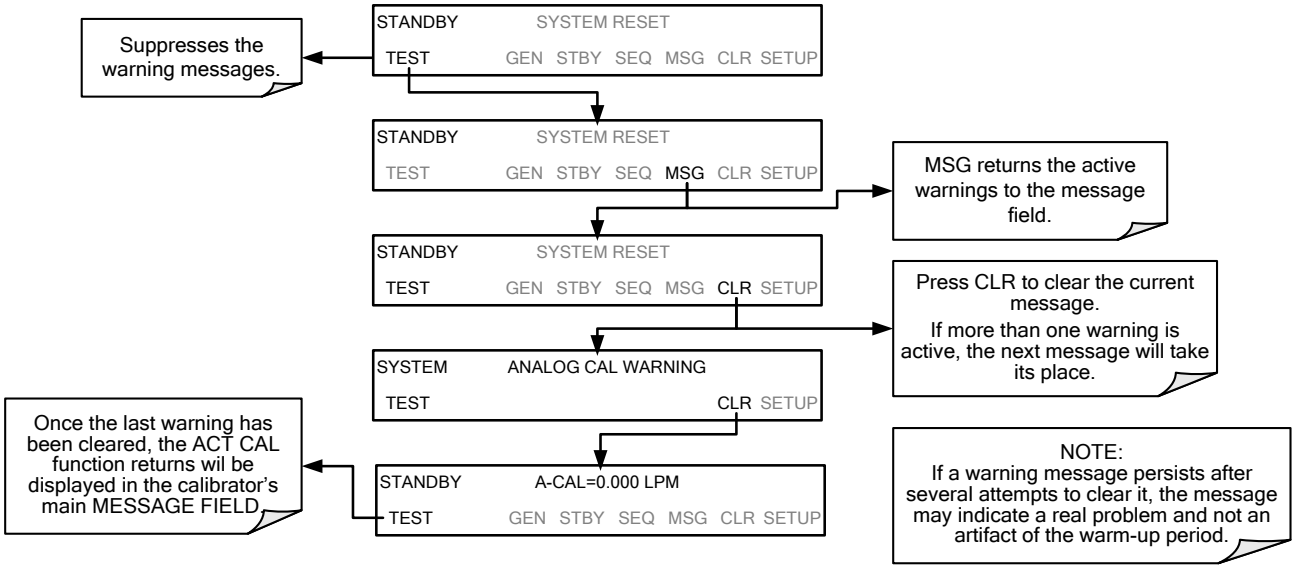


Table 3-15 lists brief descriptions of the warning messages that may occur during start up.

Table 3-15: Possible Warning Messages at Start-Up

MESSAGE	MEANING
ANALOG CAL WARNING	The calibrator's A/D converter or at least one analog input channel has not been calibrated.
CONFIG INITIALIZED	Stored Configuration information has been reset to the factory settings or has been erased.
DATA INITIALIZED	The calibrator's data storage was erased.
LAMP DRIVER WARN[1, 2]	The firmware is unable to communicate with either the O_3 generator or photometer lamp I^2C driver chips.[1, 2]
MFC CALIBRATION WARNING	The flow setting for one of the calibrator's mass flow controllers is less than 10% or greater than 100% of the flow rating for that controller.
MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.
MFC FLOW WARNING[3]	One of the calibrator's mass flow controllers is being driven at less than 10% of full scale or greater than full scale.
MFC PRESSURE WARNING	One of the calibrator's mass flow controllers internal gas pressure is outside of allowable limits.
O3 GEN LAMP TEMP WARNING[1]	The O_3 generator lamp temperature is outside of allowable limits.[1]
O3 PUMP WARNING[1]	The pump associated with the O_3 photometer has failed to turn on.[1]
PHOTO LAMP TEMP WARNING[2]	The photometer lamp temperature is outside of allowable limits.[2]
PHOTO LAMP STABILITY WARNING	Photometer lamp reference step changes occur more than 25% of the time.
PHOTO REFERENCE WARNING[2]	The photometer reference reading is outside of allowable limits.[2]
REAR BOARD NOT DET	The calibrator's motherboard was not detected during power up. - THIS WARNING only appears on Serial I/O COMM Port(s). - The LCD touchscreen will be frozen, blank or will not respond.
REGULATOR PRESSURE WARNING	The gas pressure regulator associated with the internal O_3 generator option is reporting a pressure outside of allowable limits.
RELAY BOARD WARN	The firmware is unable to communicate with the calibrator's relay PCA.
SYSTEM RESET	The calibrator has been turned off and on or the CPU was reset.
VALVE BOARD WARN	The firmware is unable to communicate with the valve controller board.

[1] Only applicable for calibrators with the optional the O_3 generator installed.

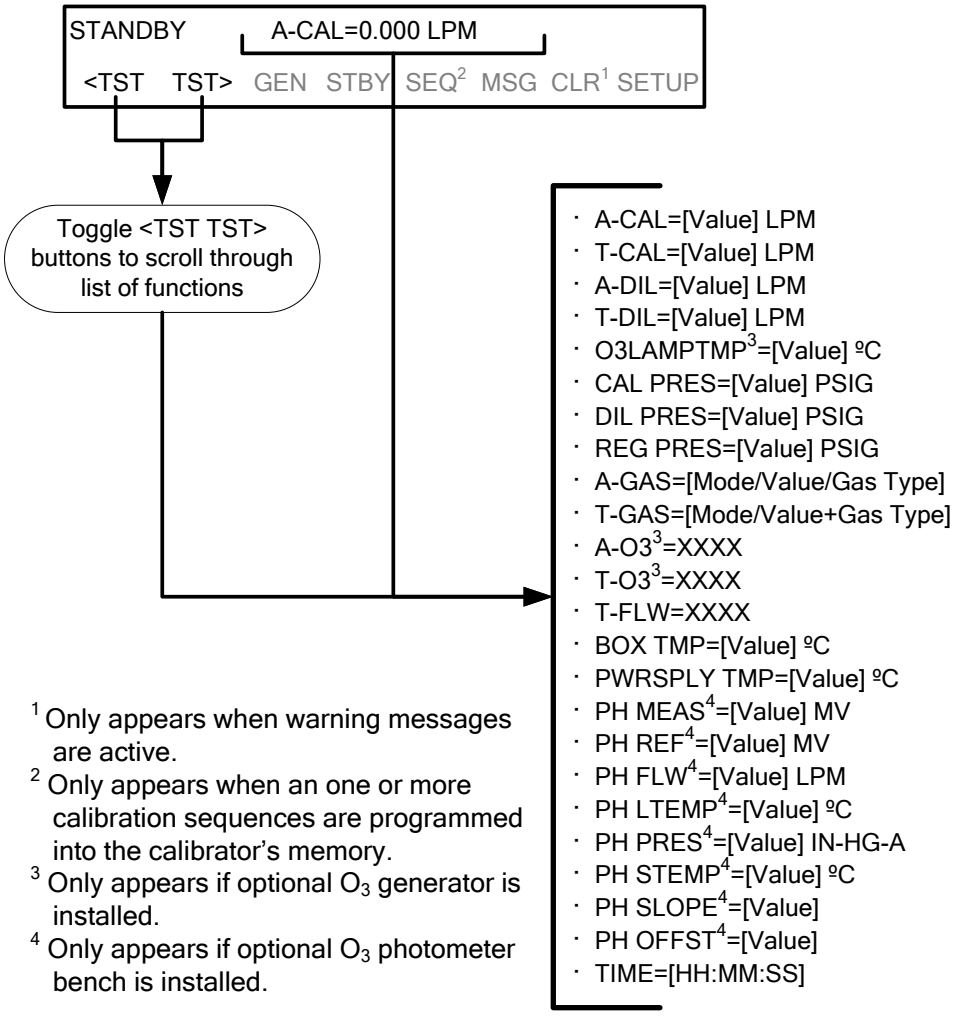
[2] Only applicable for calibrators with the optional photometer installed.

[3] On instruments with multiple Cal Gas MFCs installed, the **MFC FLOW WARNING** occurs when the flow rate requested is <10% of the range of the lowest rated MFC (i.e. all of the cal gas MFC are turned off).

3.5.3. **FUNCTIONAL CHECKS**

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

2. Check to ensure that the calibrator is functioning within allowable operating parameters. Appendix C includes a list of test functions viewable from the calibrator's LCD touchscreen as well as their expected values. These functions are also useful tools for diagnosing problems with your calibrator (Section 9.1.2). The enclosed Final Test and Validation Data sheet (P/N 05731) lists these values before the instrument left the factory.
   To view the current values of these parameters press the following button sequence on the calibrator's LCD touchscreen. Remember that until the unit has completed its warm-up, these parameters may not have stabilized.



[1] Only appears when warning messages are active.
[2] Only appears when an one or more calibration sequences are programmed into the calibrator's memory.
[3] Only appears if optional O_3 generator is installed.
[4] Only appears if optional O_3 photometer bench is installed.

3. If your calibrator is operating via Ethernet and your network is running a dynamic host configuration protocol (DHCP) software package, the Ethernet will automatically configure its interface with your LAN. However, it is a good idea to check these settings

to ensure that the DHCP has successfully downloaded the appropriate network settings from your network server (see Section 5.4.1).

4. If your network is not running DHCP or if you wish to establish a more permanent Ethernet connection, you will have to configure the calibrator's Ethernet interface manually (see Section 5.4.1.1).

3.5.4. SETTING UP THE CALIBRATION GAS INLET PORT

The T750 Portable Calibrator generates calibration gases of various concentrations by precisely mixing component gases of known concentrations with diluent (zero air). When the instrument is equipped with the optional O_3 generator and photometer, it can also use the gas phase titration method (Section 4.2.3) for generating very precise concentrations of NO_2.

In either case, it is necessary to program the concentrations of the component gases being used into the T750's memory.

3.5.5. DEFAULT GAS TYPES

The T750 calibrator is programmed with the following default gas types corresponding to the most commonly used component gases:

Table 3-16: T750 Default Gas Types

NAME	GAS TYPE
NONE	Used for gas inlet ports where no gas bottle is attached
SO_2	sulfur dioxide
H_2S	hydrogen sulfide
N_2O	nitrous oxide
NO	nitric oxide
NO_2	nitrogen dioxide
NH_3	Ammonia[1]
CO	carbon monoxide, and;
CO_2	carbon dioxide
HC	General abbreviation for hydrocarbon

[1] It is not recommended that ammonia be used in the T750.

3.5.6. **USER DEFINED GAS TYPES**

3.5.6.1. **User Defined Gas Types – General**

The T750 calibrator can accept up to four different user defined gases. This allows the use of:

- Less common component gases not included in the T750's default list;
- More than one bottle of the same gas but at different concentrations. In this case, different user-defined names are created for the different bottles of gas.

EXAMPLE: Two bottles of CO_2 are being used, allow the calibrator to create two different CO_2 calibration gases at the same flow rate.

Since identical names must not be assigned to two different bottles, one bottle can be programmed using the default name "CO2" and the other bottle programmed by assigning a user defined name such as "CO2A".

Alternatively, both bottles can be assigned user defined names; e.g. CO2A and CO2B

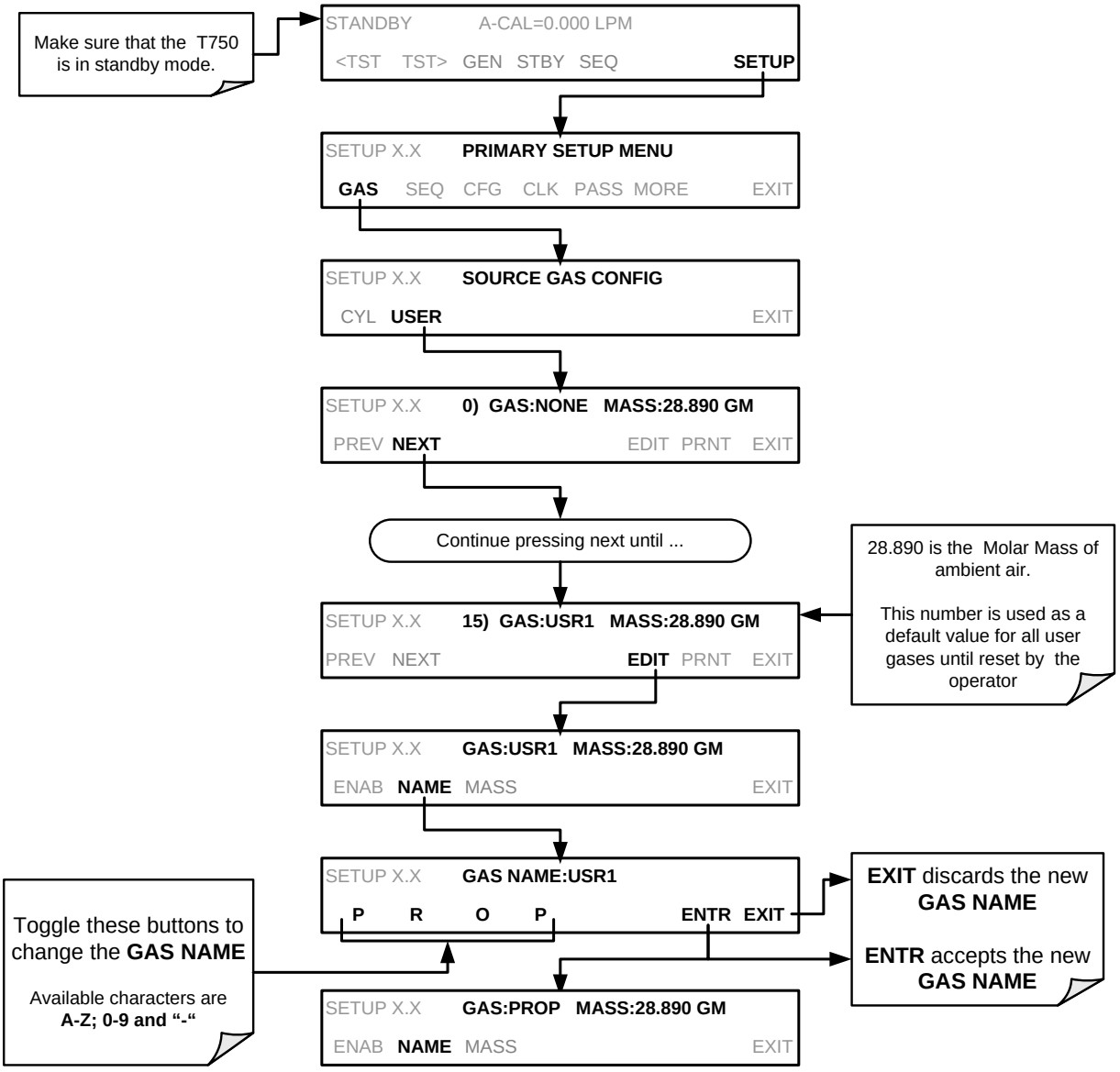
User defined gas names are added to the T750's gas library and will appear as choices during the various calibrator operations along with the default gas names listed in Section 3.5.5.

In its default state, the T750's four user defined gases are named usr1, usr2, usr3 and usr4, each with a default MOLAR mass of 28.890 (the MOLAR mass of ambient air). All four are enabled.

To define a user gas you must first define the GAS NAME and then set the MOLAR MASS.

3.5.6.2. **User Defined Gas Types – Defining the Gas Name**

In this example, we will be using PROPANE (C_2H_8). Press:



Alternatively, one could use the chemical formula for this gas, c_2h_8 or any other 4-letter name (e.g., PRPN, MY-1, etc.)

Note **If you have the same type of gas, but two different concentrations (for example, two concentrations of CO_2), assign the second concentration to one of the user defined gases (e.g. CO2 {default name} and CO2B {user defined}).**

3.5.6.3. **User Defined Gas Types – Setting the MOLAR MASS**

The molar mass of a substance is the mass, expressed in grams, of 1 mole of that 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.

EXAMPLE: The atomic weight of Carbon is 12.011 therefore the molar mass of Carbon is 12.011 grams, conversely, one mole of carbon equals the amount of carbon atoms that weighs 12.011 grams.

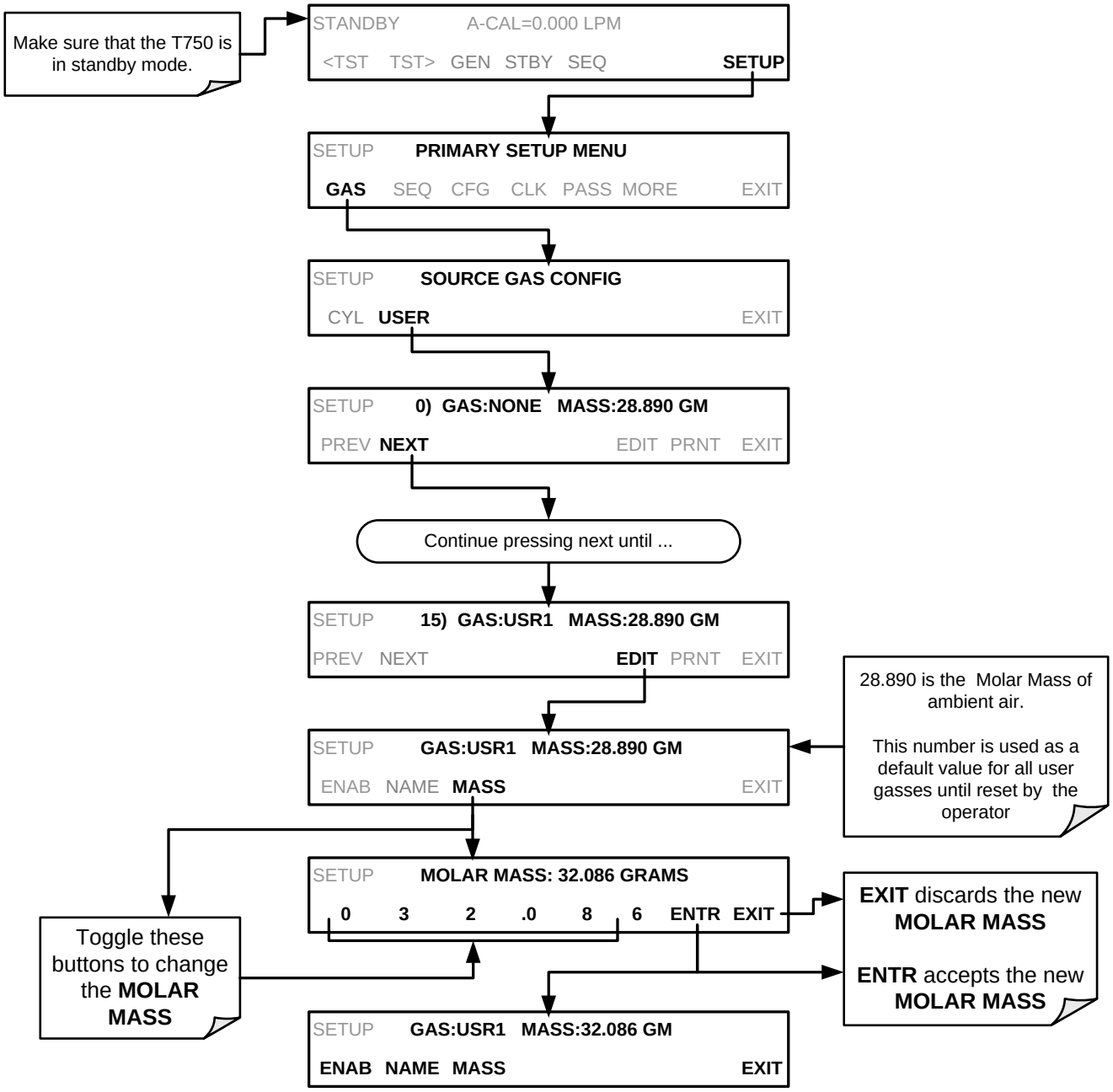
Atomic weights can be found on any Periodic Table of Elements.

To determine the Molar mass of a gas, add together the atomic weights of the elements that make up the gas.

EXAMPLE: The chemical formula for Propane is $\mathbf{C_2H_8}$. Therefore the molecular mass of propane is:

(12.011 x 2) + (1.008 x 8) = 24.022 + 8.064 = **32.086**

To set the molar mass of a user defined gas, press:

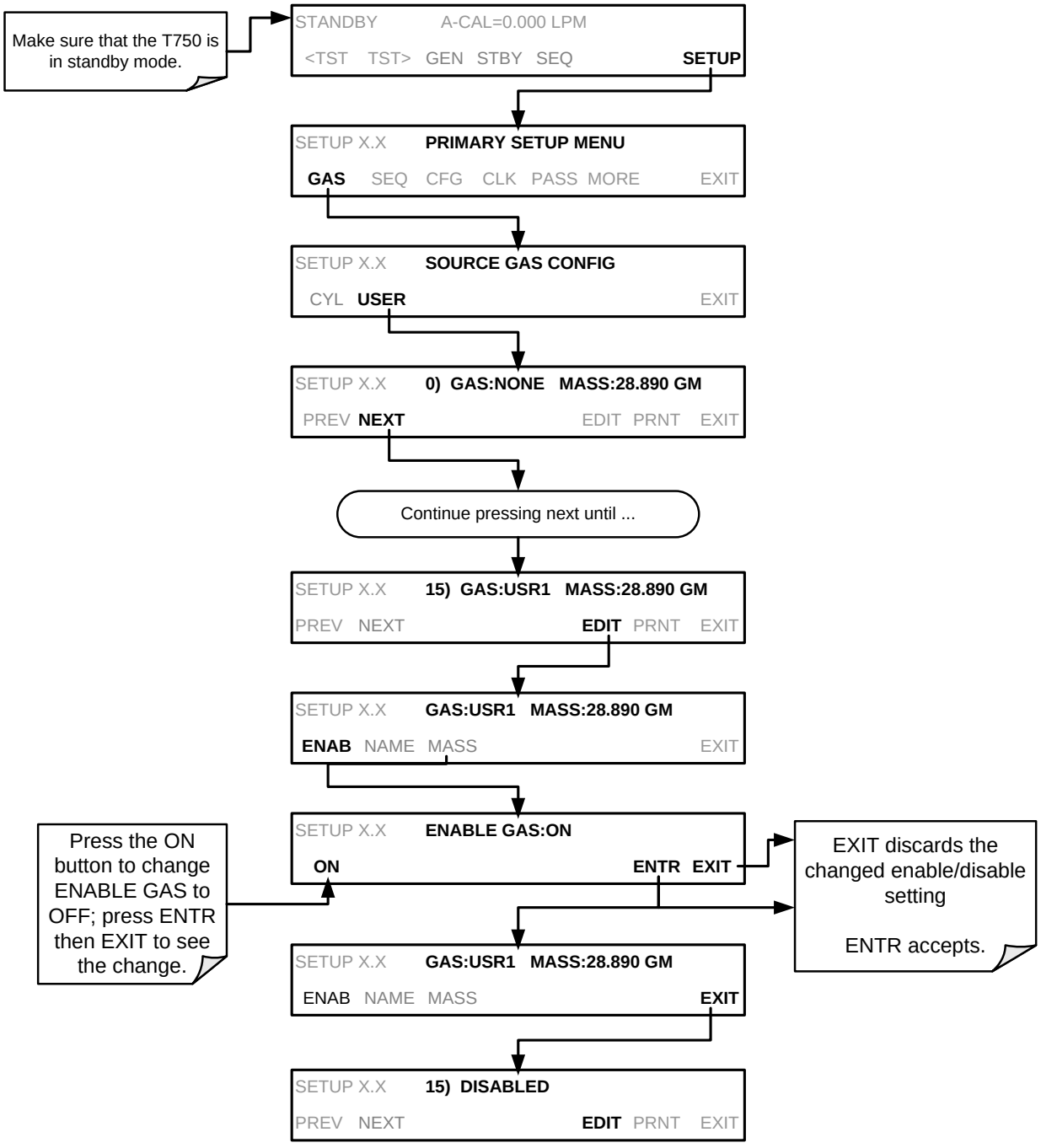


Note **If the contents of the bottle are predominantly N_2, use the molar mass of N_2 (28.01).**

3.5.6.4. **Enabling and Disabling Gas Types**

By default, all of the gases listed in Section 3.5.5 and the four undefined **USER** gases are **ENABLED.** Any of these can be disabled. Disabling a gas type means that it does not appear in certain prompts during portions of the T750's operation (e.g. setting up sequences) and is not figured into the calibrators calculating when determining calibration mixtures.

To disable a gas type, press:



3.5.7. **DEFINING THE CALIBRATION SOURCE GAS**

To set the T750 calibrator's source gas on the input port, press:

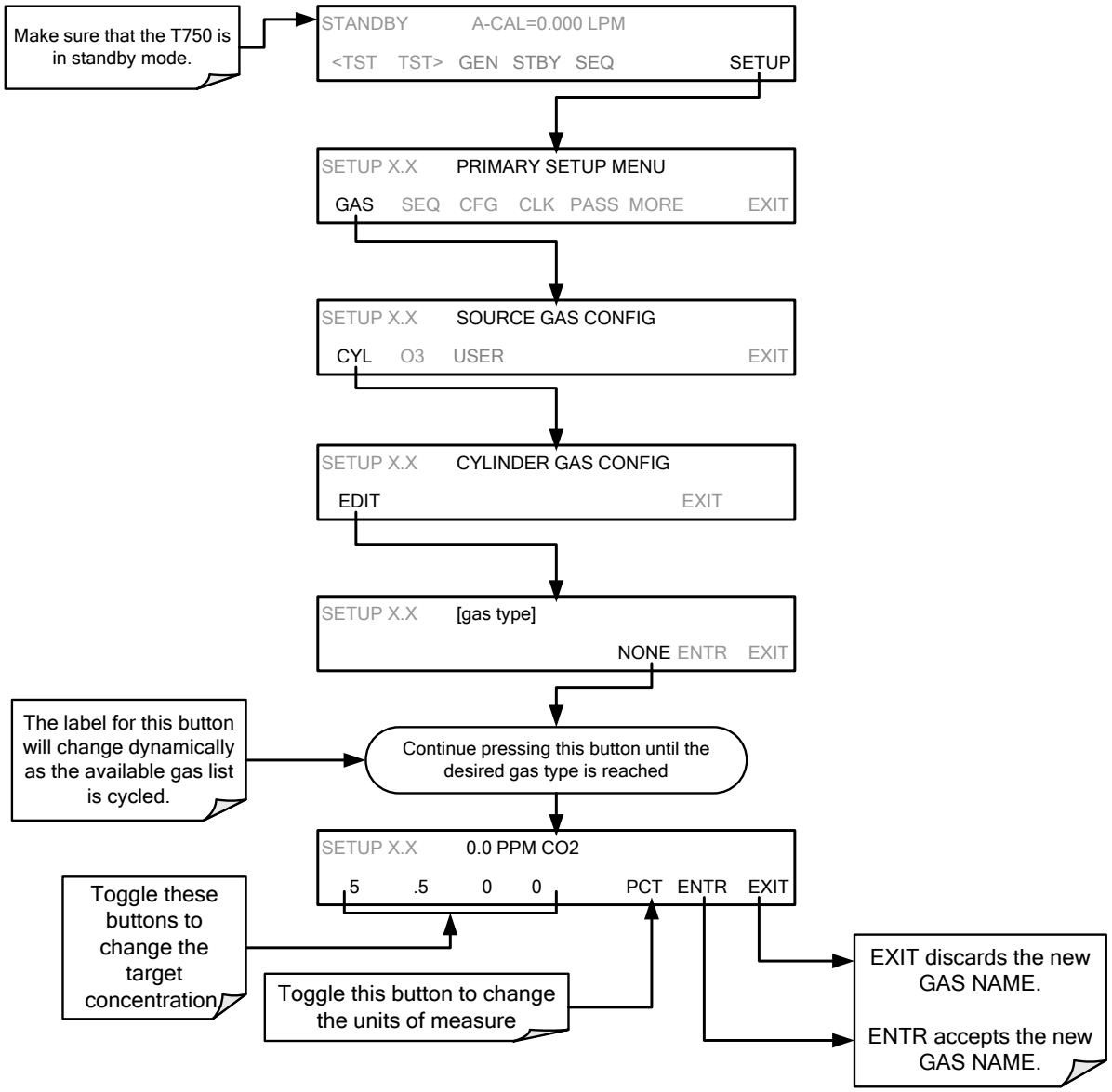


Table 3-17: T750 Units of Measure List

SYMBOL	UNITS	RESOLUTION
PPM	parts per million	000.0
PPB	parts per billion	000.0
MGM	milligrams per cubic meter	000.0
UGM	micrograms per cubic meter	000.0
PCT	percent	0.000
PPT	parts per thousand	00.00

3.5.8. SELECTING AN OPERATING MODE FOR THE O3 GENERATOR

The O_3 generator can be set to operate in either of two modes: Constant or Bench.

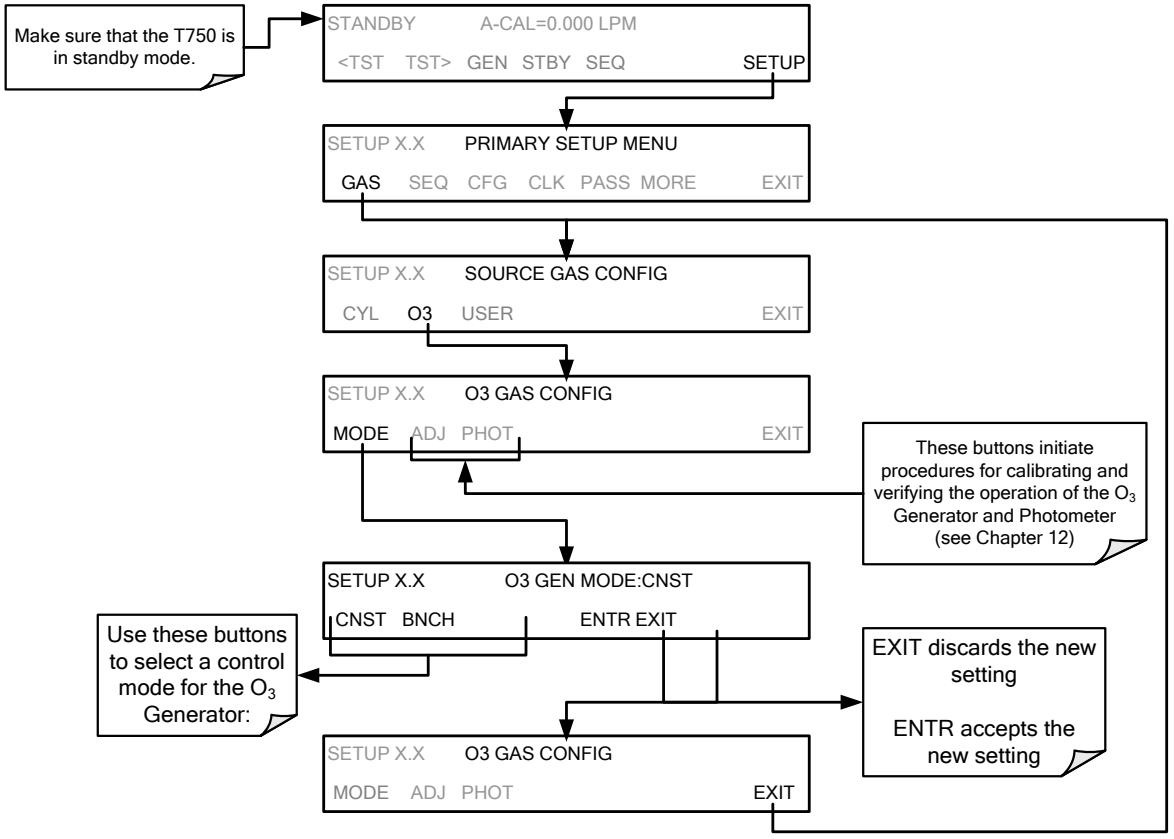
3.5.8.1. CNST (CONSTANT)

In this mode, the O_3 output of the generator is based on a single, constant, drive voltage. There is no Feedback loop control by the T750's CPU in this mode.

3.5.8.2. BNCH (BENCH)

The O_3 concentration control loop will use the photometer's O_3 measurement as input.

To select a default O_3 generator mode, press:



3.5.9. SETTING THE T750'S TOTAL GAS FLOW RATE

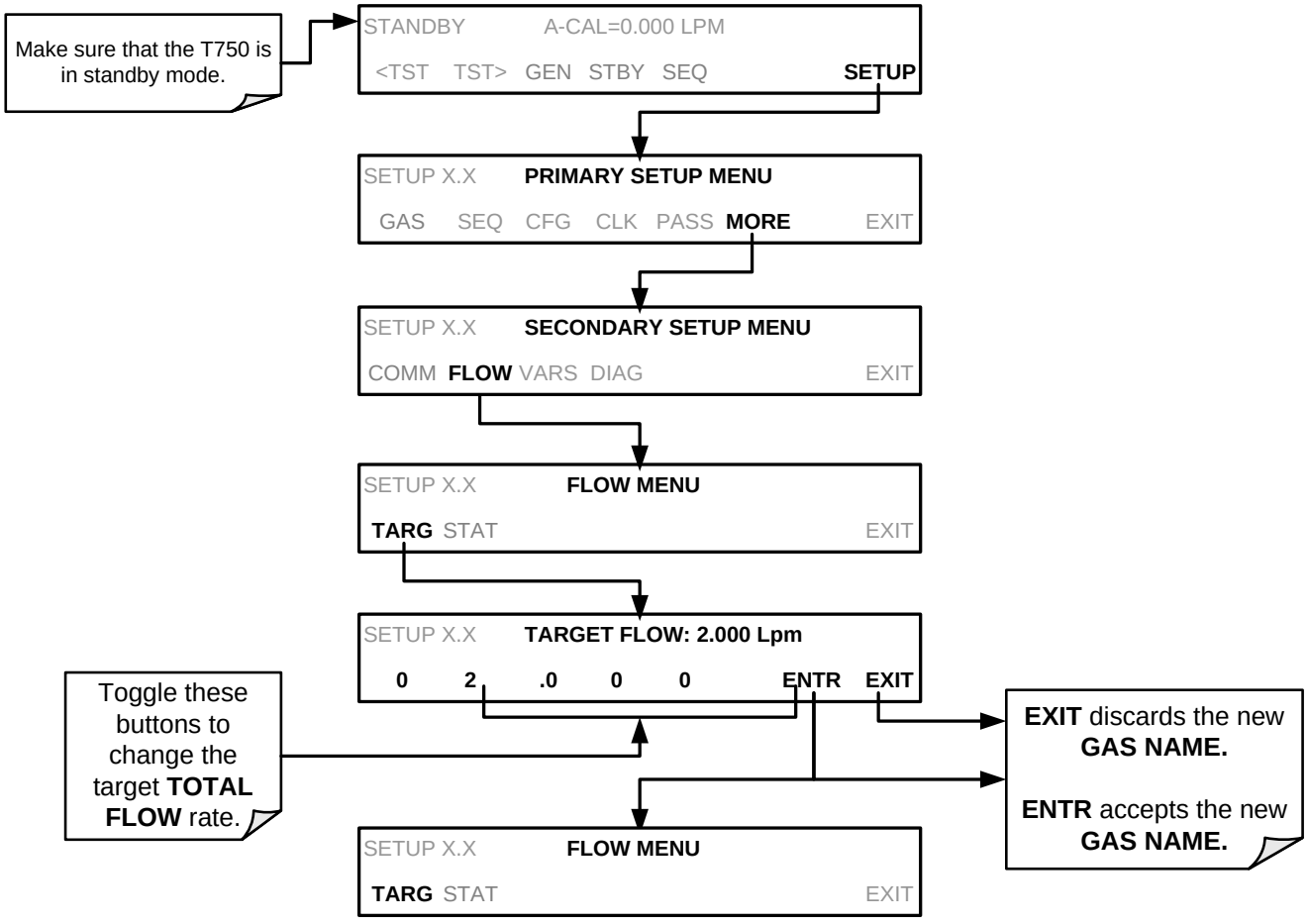
The default total gas flow rate for the T750 Portable Calibrator is 2 LPM. The calibrator uses this flow rate, along with the concentrations programmed into the calibrator for the component gas cylinders during set up, to compute individual flow rates for both diluent gas and calibration source gases in order to produce calibration mixtures that match the desired output concentrations.

This Total Flow rate may be changed to fit the user's application. Once the flow is changed, then the new flow value becomes the total flow for all the gas concentration generated and computes again the individual flow rates of the component gases and diluent accordingly.

Note

- **The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the T750 will be supplying calibration gas.**
- **Example: If the T750 is will be expected to supply calibration gas mixtures simultaneously to a system in composed of three analyzers each requiring 2 LPM, the proper Total Flow output should be set at: (2 + 2 + 2) x 1.5 = 9.000 LPM**

To set the **TOTAL FLOW** of the T750 Portable Calibrator, press:



Note

It is not recommended that you set the TOTAL FLOW rate to be <10% or >100% of the full scale rating of the diluent MFC.

The **TOTAL FLOW** is also affected by the following:

- The **GENERATE → AUTO** menu (see Section 4.2.1) or;
- As part of a **GENERATE** step when programming a sequence (see Section 4.3.2.1).

The operator can individually set both the diluent flow rate and flow rates for the component gas cylinders as part of the following:

- The **GENERATE → MANUAL** menu (see Section 4.2.2) or;
- As part of a **MANUAL** step when programming a sequence (see Section 4.3.2.5).

Note

When calculating total required flow for T750's with O_3 photometers installed ensure to account for the 800 cc/min flow it requires.

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4. OVERVIEW OF OPERATING MODES AND BASIC OPERATION

The T750 calibrator is a micro-computer-controlled calibrator with a dynamic menu interface for easy and yet powerful and flexible operation. All major operations are controlled from the LCD touchscreen.

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

Note

The flowcharts in this section depict the manner in which the LCD touchscreen is used to operate the T750 Portable Calibrator. They depict typical representations of the display during the various operations being described. They are not intended to be exact and may differ slightly from the actual display of your system.

Note

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 reappear.

The T750 calibrator software has a variety of operating modes, which are controlled from the LCD touchscreen. (Remote operation is described in Section 6). The most common mode that the calibrator will be operating in is the **STANDBY** mode. In this mode, the calibrator and all of its subsystems are inactive (no LED lit on LCD touchscreen), although **TEST** functions and **WARNING** messages are still updated and can be examined via the LCD touchscreen.

The second most important operating mode is **SETUP** mode. This mode is used for performing certain configuration operations, such as programming the concentration of source gases, setting up automatic calibration sequences and configuring the analog/digital inputs and outputs. The **SETUP** mode is also used for accessing various diagnostic tests and functions during troubleshooting.

Figure 4-1: LCD Display and Touchscreen

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

Besides **STANDBY** and **SETUP**, other operation modes are listed in Table 4-1:

Table 4-1: Calibrator Operating Modes

MODE	DESCRIPTION	
STANDBY	The calibrator and all of its subsystems are inactive.	
GENERATE	In this mode, the instrument is engaged in producing calibration gas mixtures.	
	MANUAL	In this mode, the instrument is engaged in producing calibration gas mixtures.
	GPTZ	(Gas Phase Titration Zero) The calibrator is generating a baseline NO reading with the ozone subsystem flowing gas without generating ozone. Use this mode in conjunction with the GPTS and GPT modes when performing NO_2 converter efficiency tests on NO_x analyzers.
	GPTPS[2]	(Gas Phase Titration Preset) In this mode the T750 determines the precise performance characteristics of the O_3 generator at the target values for an upcoming GPT calibration.
	GPT[1]	The calibrator is using the O_3 generator and source gas inputs to mix and generate calibration gas using the gas phase titration method.
SETUP[3]	**SETUP** mode is being used to configure the calibrator.	
	DIAG	One of the calibrator's diagnostic modes is being utilized. When the diagnostic functions that have the greatest potential to conflict with generating concentrations are active, the instrument is automatically placed into standby mode.
[1] This mode is not available in units without O_3 generators installed.		
[2] This mode is not available in units without internal photometers installed.		

4.1. STANDBY MODE

When the T750 Portable Calibrator is in standby mode, it is at rest. All internal valves are closed except the diluent inlet valve. The mass flow controllers are turned off. On units with O_3 generator and photometer options installed, these subsystems are inactive.

- The **SETUP → GAS** submenu is only available when the instrument is in **STANDBY** mode.
- Some functions under the **SETUP → MORE → DIAG** submenu, those that conflict with accurate creation of calibration gas mixtures (e.g. **ANALOG OUTPUT STEP TEST**) automatically place the calibrator into **STANDBY** mode when activated.
- The MFC pressures are not monitored in standby mode since the MFCs are turned OFF. This prevents erroneous **MASS FLOW WARNING** messages from appearing.

Note **The T750 calibrator should always be placed in STANDBY mode when not needed to produce calibration gas. The last step of any calibration sequences should always be the STANDY instruction.**

Table 4-2 shows the status of the T750's various pneumatic components when the calibrator is in **STANDBY** mode.

Table 4-2: Status of Internal Pneumatics During STANDBY Mode

VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized					MFCs			PHOT
CYL IN	**DILUENT IN**	**GPT**	**O_3 GEN[2, 3]**	**PHOT M/R[1]**	**CAL1**	**CAL2[1]**	**DILUENT**	**PUMP[2]**
X	**O**	**D**	**D**	Reference Phase	OFF	OFF	OFF	OFF

[1] Only present if multiple cal gas MFC option is installed.

[2] Present with photometer option.

[3] Present with O_3 Generator option.

In instruments with optional O_3 generators installed, airflow is maintained during **STANDBY** mode so that the generator can continue to operate at its most efficient temperature.

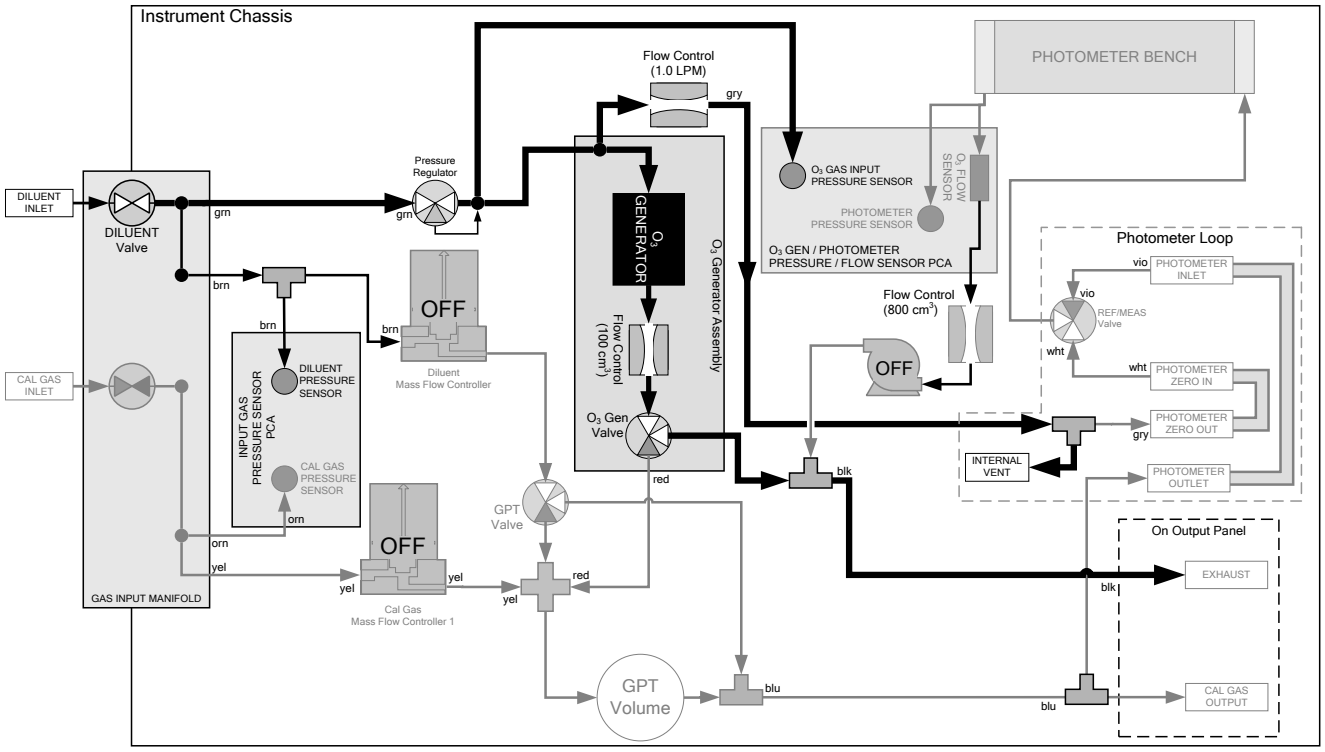


Figure 4-2: Gas Flow through T750 with O_3 Generator and Photometer Options during STANDBY

4.1.1. **TEST FUNCTIONS**

A variety of **TEST** functions are available for viewing via the LCD display whenever the calibrator is in STANDBY Mode. These functions provide information about the present operating status of the calibrator and are useful during troubleshooting (see Section 9). Table 4-3 lists the available **TEST** functions.

To view these **TEST** functions, press:

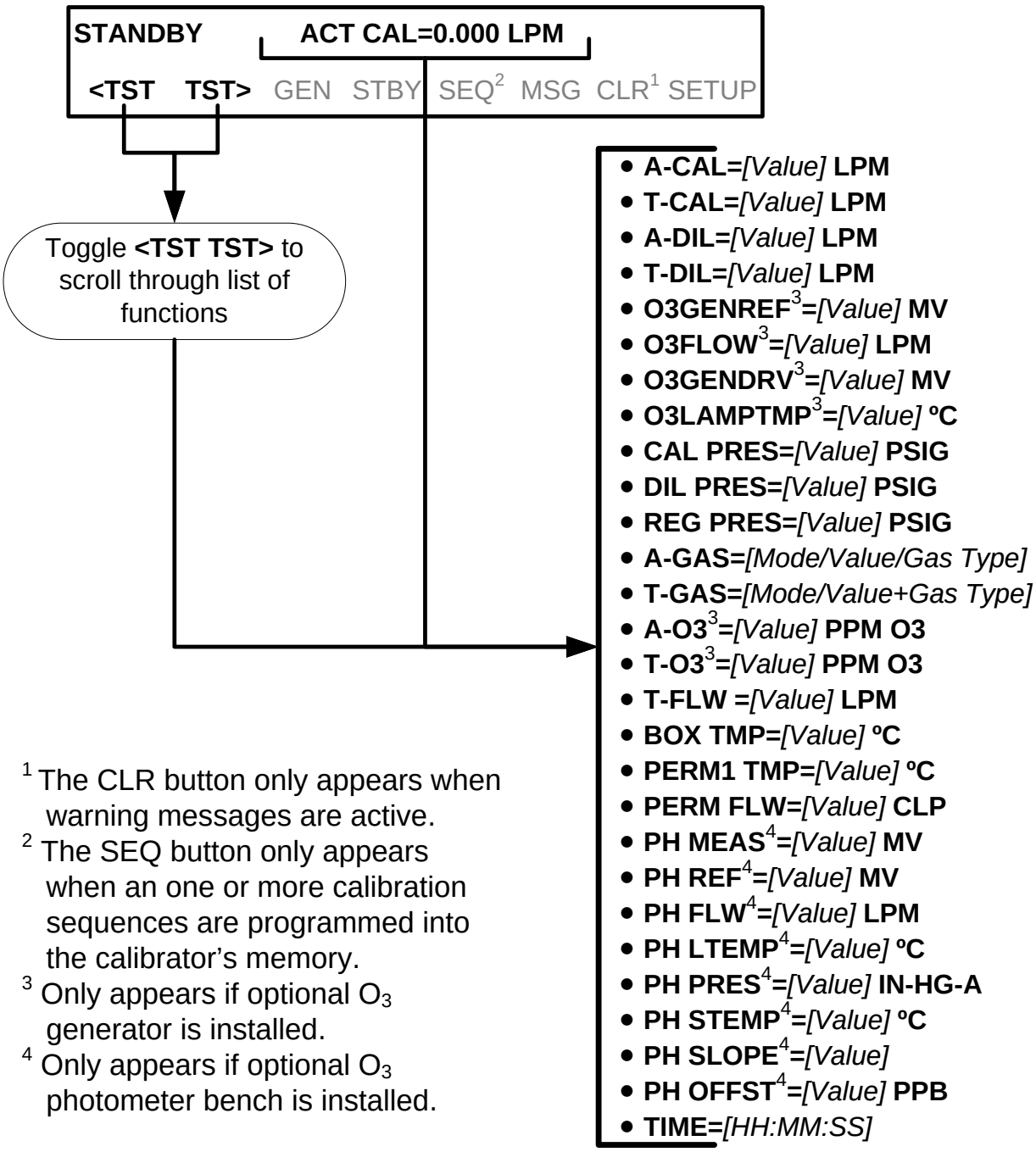


Figure 4-3: Viewing T750 Test Functions

Table 4-3: Test Functions Defined

DISPLAY	UNITS	DESCRIPTION
A-CAL	LPM	The actual gas flow rate of source gas being output by the calibrator.
T-CAL	LPM	Target source gas flow rate for which the calibrator output is set.
A-DIL	LPM	The actual gas flow rate of diluent (zero) gas being output by the calibrator.
T-DIL	LPM	The target diluent (zero) gas flow rate for which the calibrator output is set.
O3FLOW[1]	LPM	The gas flow rate for which the O_3 generator is set.
O3GENDRV[1]	mV	The drive voltage of the O_3 generator UV lamp.
O3LAMPTMP[1]	°C	O_3 generator UV lamp temperature.
CAL PRES	PSIG	The gas pressure of the source gas being supplied to the calibrator.
DIL PRES	PSIG	The gas pressure of the Diluent gas being supplied to the calibrator Diluent pressure.
REG PRES[2]	PSIG	The gas pressure at the pressure regulator on the O_3 generator supply line.
A-GAS	n/a	Actual concentration, and in some modes the actual flow rate, of the source gas in the calibration mixture being generated is displayed.
T-GAS	n/a	The target concentration of the source gas in the calibration mixture being generated is displayed.
T-FLW	n/a	The target flow.
BOX TMP	°C	Temperature of the internal chassis.
PWRSPLY TMP	°C	Temperature within the power supply cage.
PH MEAS[2]	mV	The average UV Detector output during the SAMPLE PORTION of the optional photometer's measurement cycle.
PH REF[2]	mV	The average UV Detector output during the REFERENCE portion of the optional photometer's measurement reference cycle.
PH FLW[2]	LPM	The gas flow rate as measured by the flow sensor located between the optical bench and the internal pump.
PH LTEMP[2]	°C	The temperature of the UV lamp in the photometer bench.
PH PRES[2]	In-hg-A	The pressure of the gas inside the photometer's sample chamber as measured by a solid-state pressure sensor located downstream of the photometer.
PH STEMP[2]	°C	The temperature of the gas inside the sample chamber of the photometer.
PH SLOPE[2]	1.000	Photometer slope computed when the photometer was calibrated at the factory.
PH OFFST[2]	ppb	Photometer offset computed when the photometer was calibrated at the factory.
TEST[3]	mV	Displays the analog signal level of the **TEST** analog output channel.
TIME	HH:MM:SS	Current time as determined by the calibrator's internal clock.

[1] Only appears when the optional O_3 generator is installed.

[2] Only appears when the optional O_3 photometer is installed.

[3] Only appears when the **TEST** channel has been activated.

4.2. GENERATE MODE

The Generate Mode allows the user to generate the desired calibration gas mixtures. The types of gas include NO, NO_2, SO_2, CO, HC or ZERO gas based on the source gas concentration entered during initial setup (see Section 3.5.7). If the unit has an optional O_3 generator installed, various concentrations of O_3 can be generated as well.

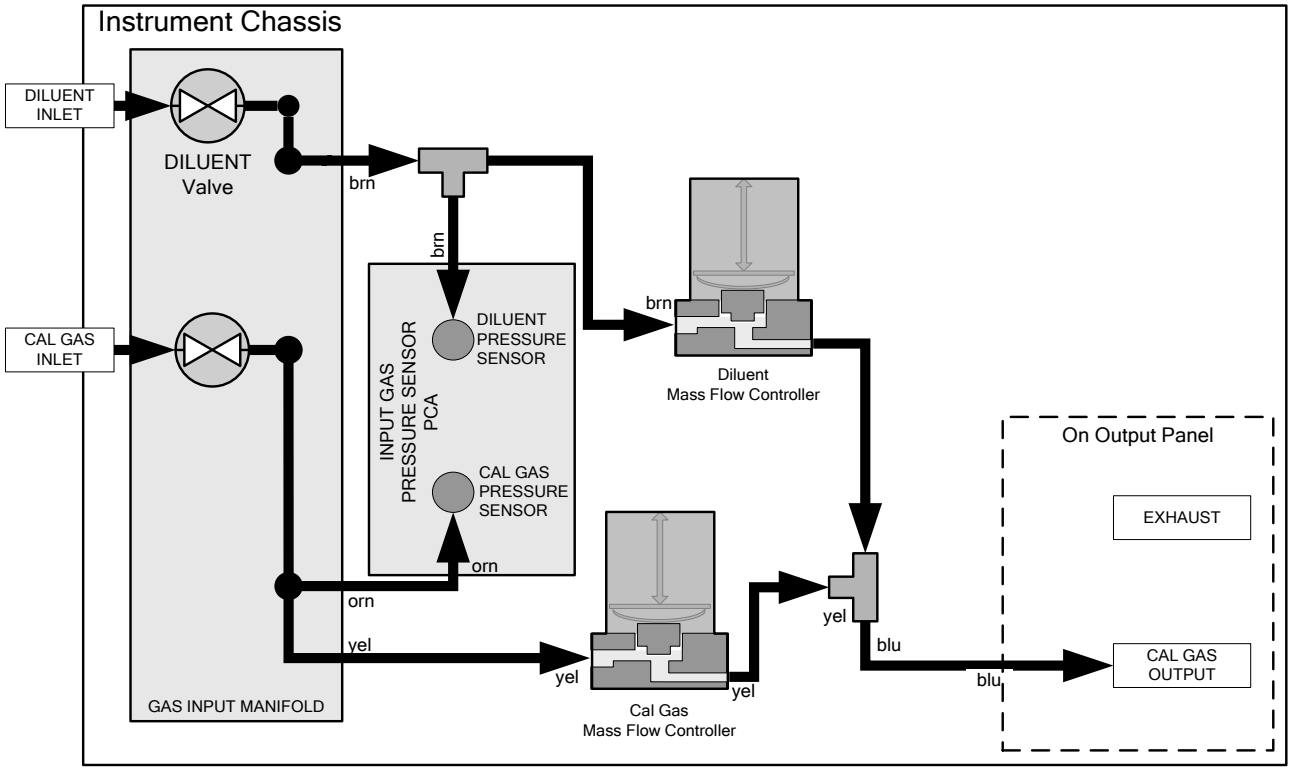


Figure 4-4: Gas Flow through Basic T750 in GENERATE Mode

Table 4-4 shows the status of the T750's various pneumatic components when the calibrator is in **GENERATE** mode:

Table 4-4: Status of Internal Pneumatics During GENERATE Mode

GAS TYPE	VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized)					MFCs			PHOT PUMP[3]
	CYL IN	DILUENT IN	GPT	O_3 GEN[4]	PHOT M/R[1]	CAL1	CAL2[1]	DILUENT	
Generate Source Gas	**O**	**O**	**D**	**D**	Reference Phase	**ON[2]**	**ON[2]**	**ON**	**OFF**
Generate O_3	**X**	**O**	**D**	**E**	Switching	**OFF**	**OFF**	**OFF**	**ON**

[1] Only present if multiple cal gas MFC option is installed.

[2] In instruments with multiple MFCs, the CPU chooses which MFC to use depending on the target gas flow requested.

[3] Present with photometer option.

[4] Present with O_3 Generator option.

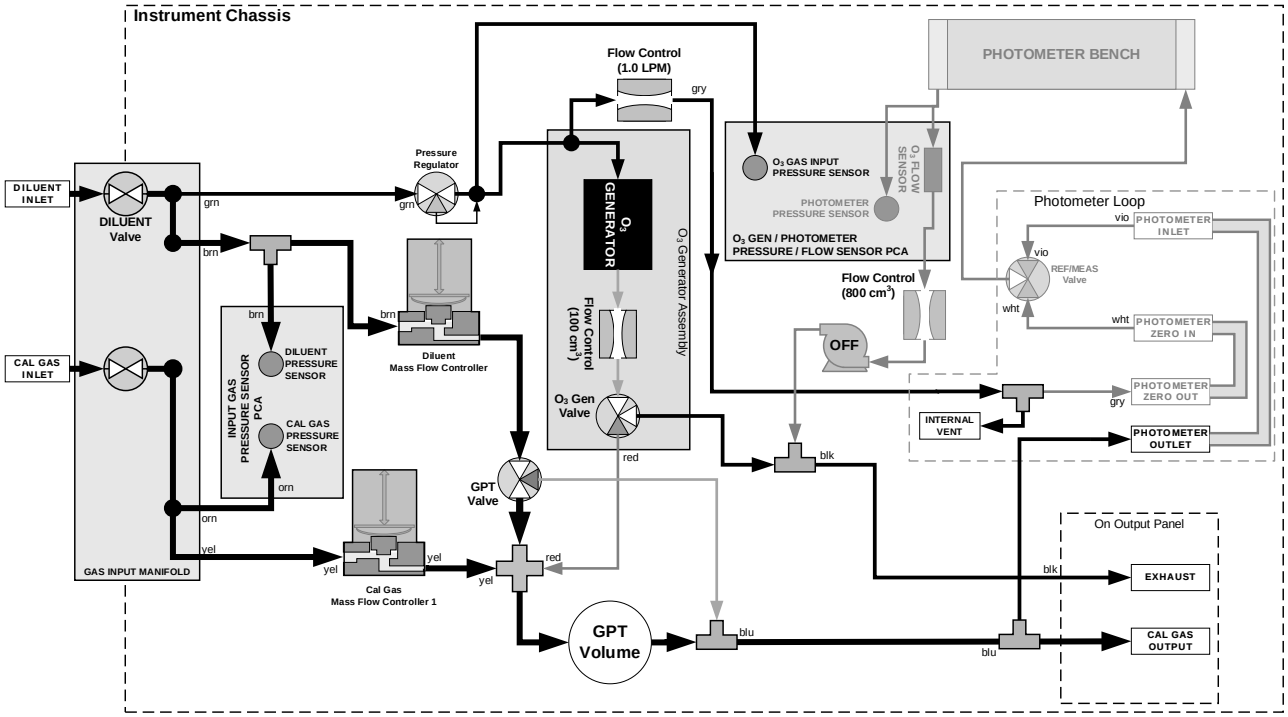


Figure 4-5: Gas Flow through T750 with O_3 Options when Generating Non-O_3 Source Gas

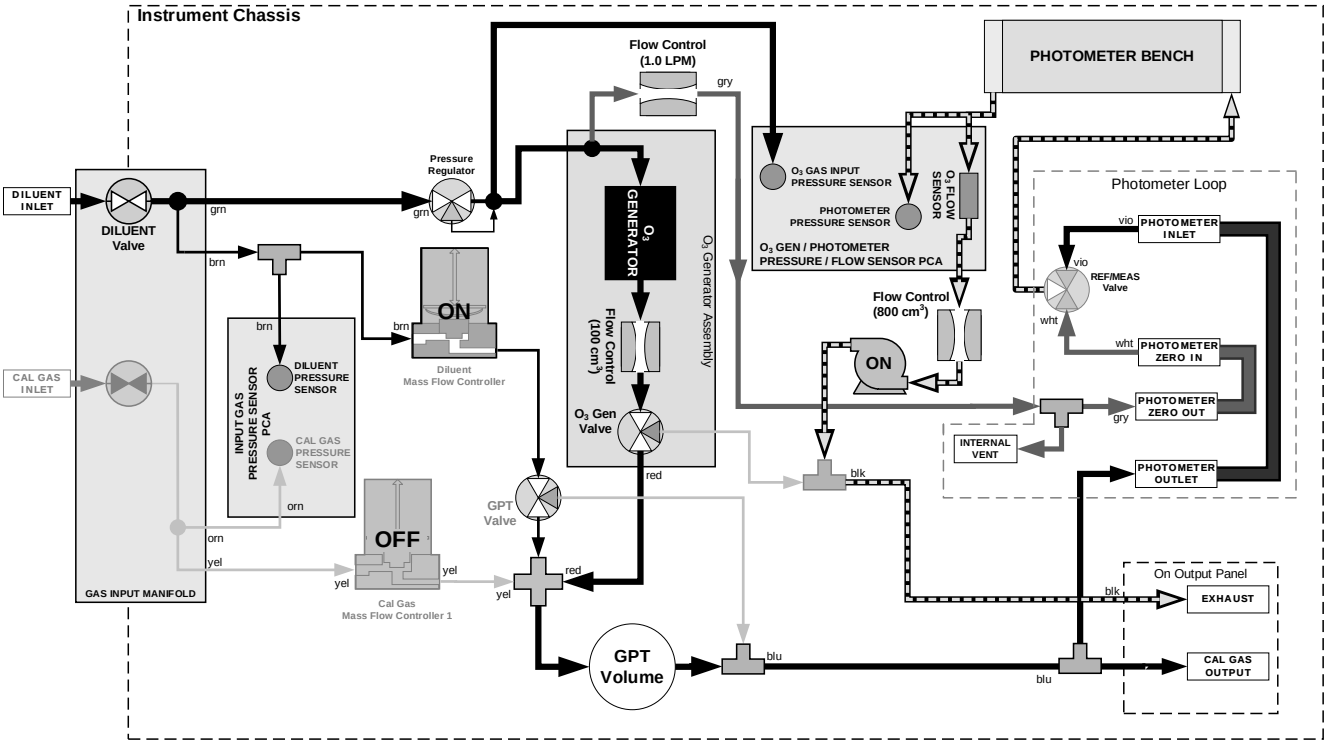


Figure 4-6: Gas Flow through T750 with O_3 Options when Generating O_3

4.2.1. GENERATE → AUTO: BASIC GENERATION OF CALIBRATION MIXTURES

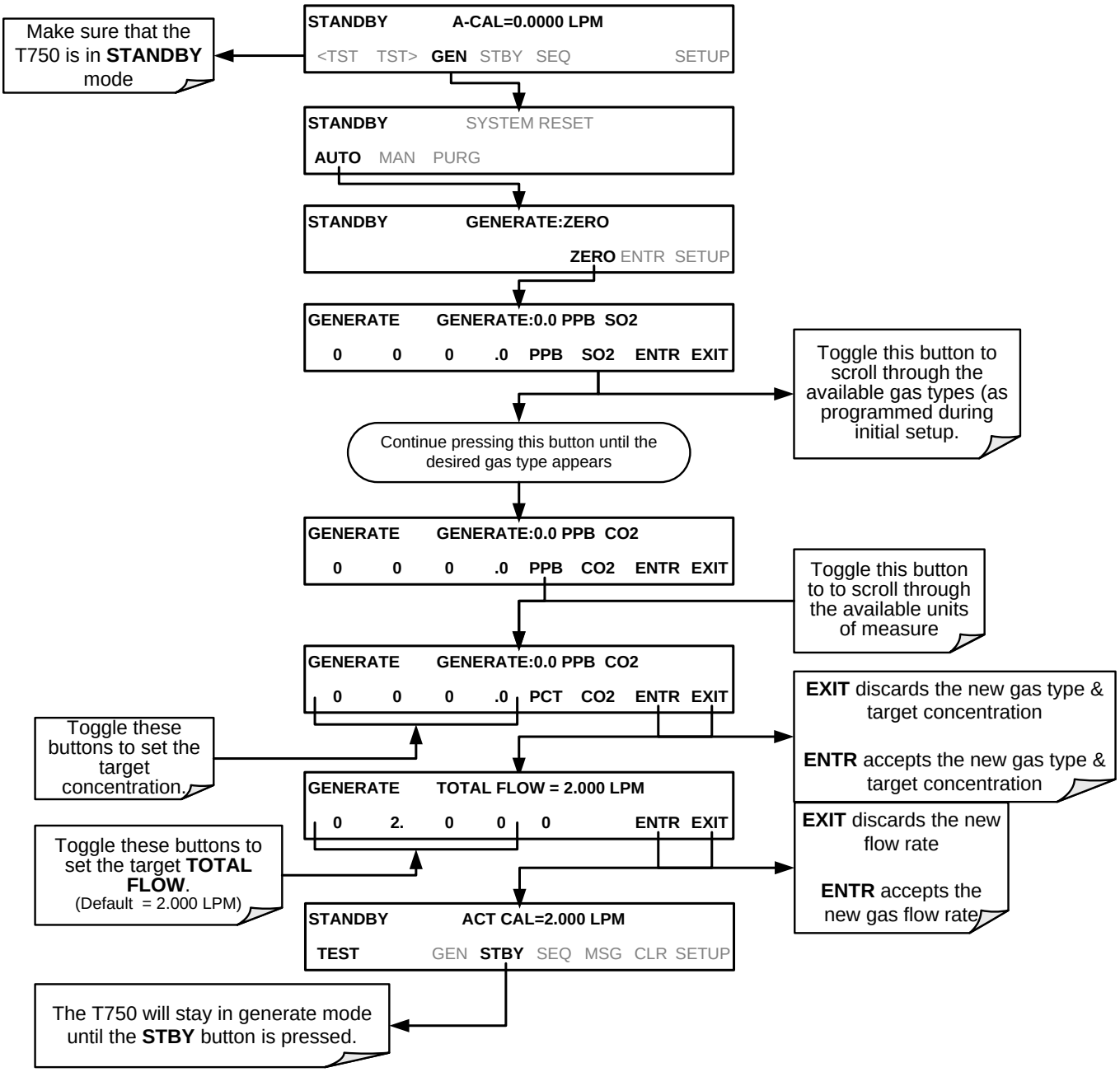
This is the simplest procedure for generating calibration gas mixtures. In this mode, the user makes three choices:

- The type of component gas to be used from the list of gases input during initial set up (see Section 3.5.7);
- The target concentration, and;
- The **TOTAL FLOW** to be output by the T750.

Using this information, the T750 calibrator automatically calculates and sets the individual flow rates for the Diluent and chosen component gases to create the desired calibration mixture.

Note **This menu, which shows the SEQ (sequence) button, differs from the GENERATE>AUTO menu for cylinders of multiple gases (Section 4.2.7).**

To use the **GENERATE → AUTO** feature, press:



4.2.2. GENERATE → MAN: GENERATING CALIBRATION MIXTURES MANUALLY

This mode provides complete the user with more complete control of the gas mixture process. Unlike the **AUTO** mode, **MAN** mode requires the user set the both the component gas flow rate and diluent airflow rate. This allows the user control over the mixing ratio and total calibration gas flow rate.

In addition, if the T750 calibrator is equipped with the optional O_3 generator, and O_3 is to be included in the calibration mixture (e.g. using the GPT or GPTPS features), the user also needs to set the ozone generator mode and set point.

The **TOTAL FLOW** is defined by the user depending on system requirements.

Note

- **The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the T750 will be supplying calibration gas.**
- **Example: If the T750 is will be expected to supply calibration gas mixtures simultaneously to a system in composed of three analyzers each requiring 2 LPM , the proper Total Flow output should be set at:**

(2 + 2 + 2) x 1.5 = 9.000 LPM

4.2.2.1. Determining the Source Gas Flow Rate

To determine the required flow rate of the component source gas use the following formula

Equation 4-1

$$GAS_{flow} = \frac{C_f \times Totalflow}{C_i}$$

WHERE:

C_f = target concentration of diluted gas
C_i = concentration of the source gas
GAS_{flow} = source gas flow rate

EXAMPLE:

- A target concentration of 200 ppm of SO_2 is needed.
- The Concentration of the SO_2 Source is 600 ppm
- The requirement of the system are 9.000 LPM
- The required source gas flow rate would be:

GAS_{flow} = (200 ppm x 9.000 LPM) ÷ 600 ppm
GAS_{flow} = 1800.000 ppm/LPM) ÷ 600 ppm
GAS_{flow} = 3.000 LPM

4.2.2.2. **Determining the Diluent Gas Flow Rate**

To determine the required flow rate of the diluent gas use the following formula:

Equation 4-2

$$DIL_{flow} = Totalflow - GAS_{flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system

DIL_{flow} = required diluent gas flow

EXAMPLE:

- If the requirement of the system is 9.000 LPM,
- The source gas flow rate is set at 3.00 LPM.
- The required source gas flow rate would be:

DIL_{flow} = 9.0 LPM – 3.0 LPM
DIL_{flow} = 6.0 LPM

4.2.2.3. **Determining the Diluent Gas Flow Rate with the Optional O_3 Generator Installed**

If the optional O_3 generator is installed and in use, Equation 6.2 will be slightly different, since the O_{3flow} is a constant value and is displayed as a **TEST** function on the T750's LCD displayTable 3-1. A typical value for O_{3flow} is 105 cm^3/min.

Equation 4-3

$$DIL_{flow} = Totalflow - O_{3\,flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system.

$O_{3\,flow}$ = the flow rate set for the O_3 generator; a constant value (typically about 0.105 LPM)

DIL_{flow} = required diluent gas flow

EXAMPLE:

- If the requirement of the system are 9.000 LPM,
- The source gas flow rate is set at 3.00 LPM.
- The required source gas flow rate would be:

DIL_{flow} = 9.0 LPM – 0.105 LPM
DIL_{flow} = 8.895 LPM

Note

It is not recommended to set any flow rate to <10% or >100% of the full scale rating of that associated mass flow controller.

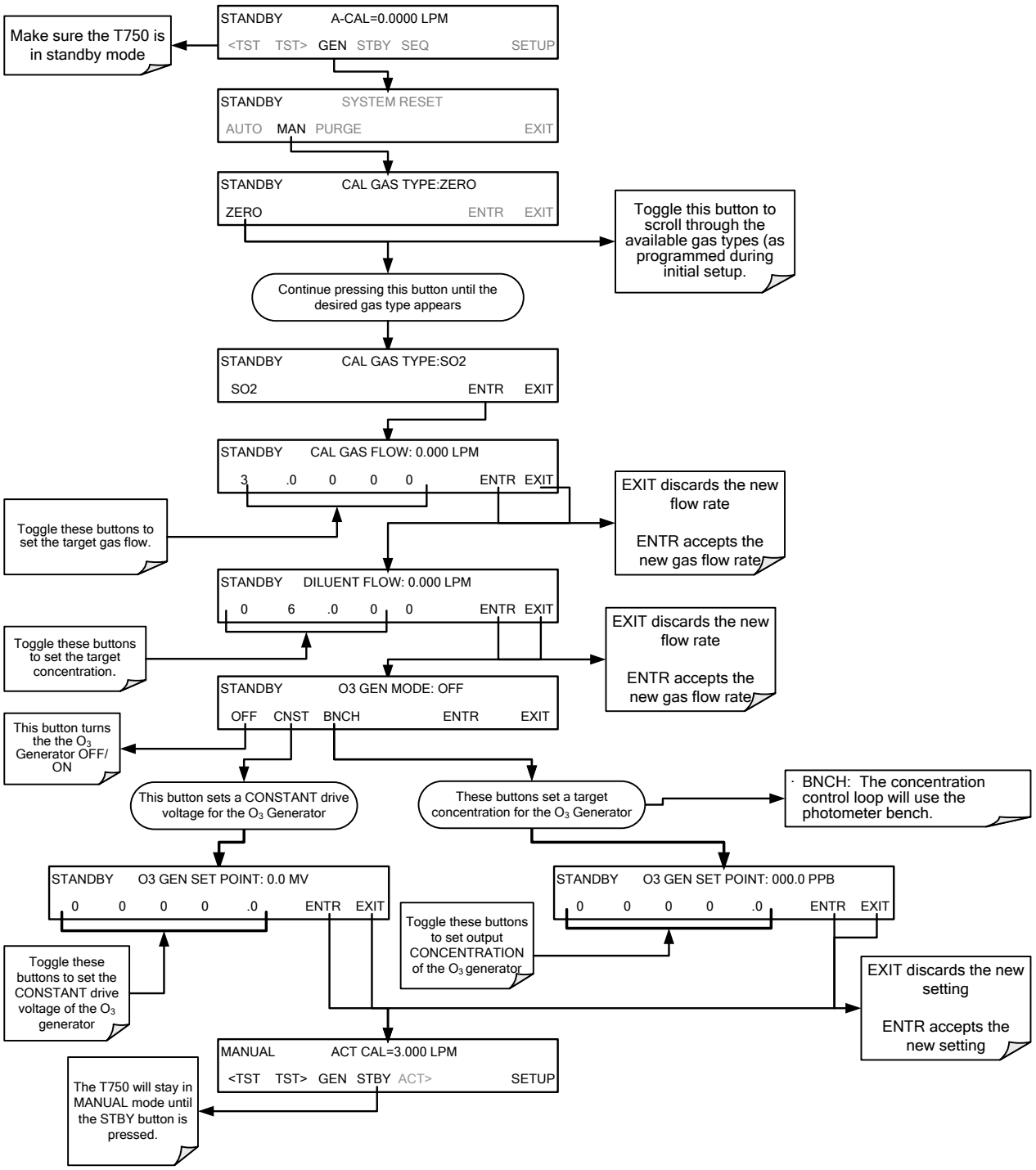
WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED:

- **The combined flow potential of both mass flow controllers is available with the following limits: The limits are <10% of the lowest rated MFC or >100% of the combined full-scale ratings for both mass flow controllers.**
- **The T750 will automatically select the MFC with the lowest flow rate that can accommodate the requested flow, thereby affording the most precise flow control.**
- **If no single MFC can accommodate the requested flow rate, multiple mass flow controllers are used.**

4.2.2.4. **Setting the Source Gas and Diluent Flow Rates Using the GENERATE → MAN Menu**

In the following demonstration we will be using the values from the examples given with Equations 6-1 and 6-2 above and assume a T750 calibrator with at least one source gas mass flow controller capable of 3.0 LPM output.

Using the example from Equations 6-1 and 6-2 above, press:



4.2.3. GENERATE → GPTZ, GPTPS, GPT: UNDERSTANDING GAS PHASE TITRATION (GPT)

Gas phase titration (GPT) provides an alternative method to UV photometry for ozone analysis. This section first describes the principles of GPT, then provides the information necessary for performing GPTZ, GPT Preset (GPTPS), and GPT.

Note

It is strongly recommended that GPTZ and GPTPS be performed prior to running GPT.

4.2.3.1. GPT Theory

The principle of GPT is based on the rapid gas phase reaction between NO and O_3, which produces quantities of NO_2 as shown by the following equation:

Equation 4-4

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu_{(light)}$$

It has been empirically determined that under controlled circumstances the NO-O_3 reaction is very efficient (<1% residual O_3), therefore the concentration of NO_2 resulting from the mixing of NO and O_3 can be precisely predicted and controlled as long as the following conditions are met:

- The amount of O_3 used in the mixture is known.
- The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount of O_3 in the mixture.
- The volume of the mixing chamber is known.
- The NO and O_3 flow rates (from which the time the two gases are in the mixing chamber) are low enough to give a residence time of the reactants in the mixing chamber of >2.75 ppm min.

Given the above conditions, the amount of NO_2 being output by the T750 will be equal to (at a 1:1 ratio) to the amount of O_3 added.

Since the O_3 flow rate of the T750's O_3 generator is a set fixed value (typically about 0.105 LPM) and the GPT chamber's volume is known, once the **TOTAL GAS FLOW** requirements, the source concentration of NO, and the target concentration for the O_3 generator are entered into the calibrator's software. The T750 adjusts the NO flow rate and diluent (zero air) flow rate to create the appropriate NO_2 concentration at the output.

4.2.3.2. Choosing an Input Concentration for the NO

It is important to ensure that there is enough NO in the GPT chamber to use up all of the O_3. Excess O_3 will react with the resulting NO_2 to produce NO_3. Since NO_3 is undetectable by most NO_x analyzers, this will result in false low readings.

The EPA requires that the NO content of a GPT mixture be at least 10% higher than the O_3 content. Since there is no negative effect to having too much NO in the GPT chamber, Teledyne API recommends that the NO concentration be chosen to be some value higher (as much as twice as high) as the highest intended target NO_2 value and kept constant.

As long as the flow rate remains constant, three of the four conditions listed in Section 4.2.3.1 above are therefore constant and the NO_2 output can be easily and reliably varied by simply changing the O_3 concentration.

EXAMPLE:

- Calibration values of NO_2 from 200 ppb to 450 ppb will be needed.
- The NO gas input concentration should be no lower than 495 ppb and can be as high as 900 ppb.

4.2.3.3. **Determining the TOTAL FLOW for GPT Calibration Mixtures**

The total flow rate is defined by the user depending on system requirements.

The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the T750 will be supplying calibration gas.

EXAMPLE:

- If the T750 will be expected to supply calibration gas mixtures simultaneously to a system composed of three analyzers, each requiring 2 LPM, the proper Total Flow output should be set at:

$$(2 + 2 + 2) \times 1.5 = 9.000 \text{ LPM}$$

Note

It is not recommended to set any flow rate to <10% or >100% of the full scale rating of that associated mass flow controller.

WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED:

- **The full combined flow potential of both mass flow controllers is available to use with the following limits: 10% of the lowest rated MFC to 100% of the combined full-scale ratings for both mass flow controllers.**
- **The T750 automatically selects the MFC with the lowest flow rate that can accommodate the requested flow, thereby affording the most precise flow control.**
- **If no single MFC can accommodate the requested flow rate, multiple mass flow controllers are used.**

Given this information, the T750 calibrator determines the NO gas flow by the formula:

Equation 4-5

$$NO\ GAS_{flow} = \frac{C_{NO_2} \times Totalflow}{C_{NO}}$$

WHERE:

C_{NO2} = target concentration for the NO_2 output

C_{NO} = concentration of the NO gas input

$NO\ GAS_{flow}$ = NO source gas flow rate

And the diluent (zero air) gas flow by the formula:

Equation 4-6

$$DIL_{flow} = Totalflow - NO\ GAS_{flow} - O_{3\ flow}$$

WHERE:

GAS_{flow} = source gas flow rate (from Equation 6-1)

Totalflow = total gas flow requirements of the system.

$O_{3\ flow}$ = the flow rate set for the O_3 generator; a constant value (typically about 0.105 LPM)

DIL_{flow} = required diluent gas flow

4.2.4. GENERATE → GPTZ: GENERATING GPT FLOW CONDITIONS (TO BE RUN PRIOR TO PERFORMING GPTPS AND GPT)

To evaluate and calculate the catalytic converter efficiency (CE), GPTZ should be run first for best accuracy of GPT. GPTZ simulates the flow condition of GPT without generating ozone. This provides accuracy of the NO reading.

Note **Note that the ozone lamp does not turn on during GPTZ.**

4.2.4.1. T750 Calibrator GPTZ Operation

The following table and figure show the status of the T750's internal pneumatic components and internal gas flow when the instrument is in **GPTZ** generating mode.

Table 4-5: Status of Internal Pneumatics During GENERATE → GPTZ Mode

MODE	VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized					MFCs			PHOT PUMP[3]
	CYL IN	DILUENT IN	GPT	O_3 GEN[3, 4]	PHOT M/R[1]	CAL1	CAL2[1]	DILUENT	
GPTZ	O	O	E	E	Reference Phase	ON[2]	ON[2]	ON	OFF

[1] Only present if multiple cal gas MFC option is installed.

[2] In instruments with multiple MFCs, the CPU chooses which MFC to use depending on the target gas flow requested.

[3] Present with photometer option.

[4] Present with O_3 generator option.

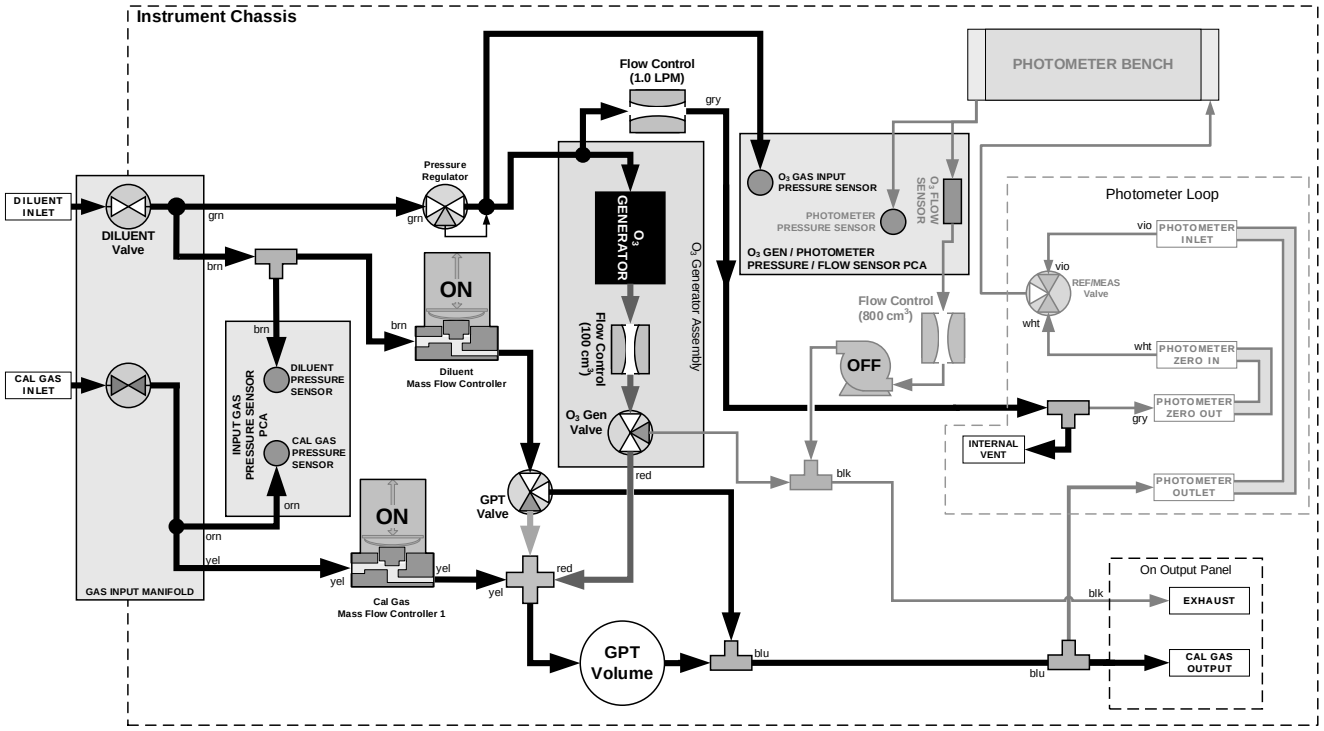
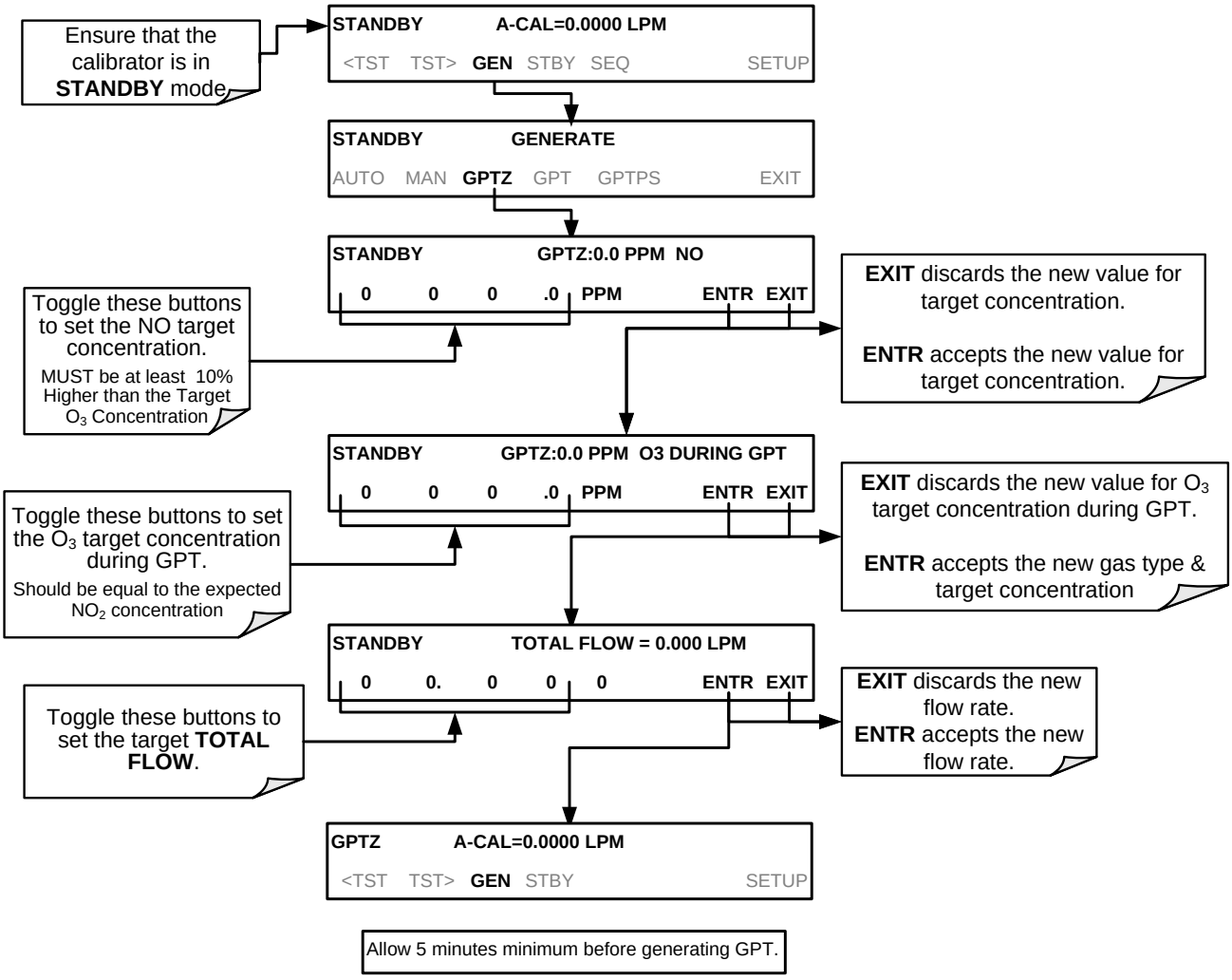


Figure 4-7: Gas Flow through T750 with O_3 Options when in GPTZ Mode

To initiate GPTZ gas generation you will need to know:

- NO source gas concentration
- Target O_3 concentration (equal to the target NO_2 concentration to be generated)
- TOTAL GAS FLOW for the mixture output

Then, press:



4.2.5. GENERATE → GPTPS: PERFORMING A GAS PHASE TITRATION PRE-SET (TO BE RUN AFTER GPTZ AND PRIOR TO GPT)

The GPT Pre-Set (GPTPS) feature *simulates* a **GPT** mixing operation in order to determine the *exact output* of the calibrator's O_3 generator. As described in Section 4.2.3.1, all other things being equal, the concentration of the NO_2 being generated by the GPT feature will be equal to the amount of O_3 used. Therefore, the more accurately the O_3 generator performs, the more accurate the NO_2 output will be.

When operating in **GPTPS** mode, diluent gas (zero air) is substituted for the NO gas that would be mixed with the O_3 in normal GPT mode. The resulting unaffected O_3 output of the O_3 generator is shunted through the T750's internal photometer, which measures the ACTUAL O_3 concentration in the gas.

Once the *exact* O_3 concentration being output by the generator is determined, the calibrator's software adjusts the O_3 drive voltage up or down so that the output of the generator matches as closely as possible, the target concentration requested. This adjusted generator setting will be used during any subsequent real GPT operation.

Note **The T750 has a learning algorithm during the O_3 generation (see Section 4.2) or Gas Phase Titration Pre-Set Mode (GPTPS). It may take up to one hour for each new concentration/flow (point) that is entered into the instrument. Once the instrument has several points memorized in its cache, any new point that is entered will automatically be estimated within ±1% error (with photometer) and ±10% error (with O_3 generator and GPTPS).**

Note **This adjustment is only valid for the O_3 concentration used during the Pre-Set operation. GPT Pre-Sets must be re-run for each different target NO_2 value.**

In order to keep the resulting concentration of O_3 consistent with the GPT mixture being simulated, the instrument's software adjusts the flow rate of the diluent gas to substitute an amount of diluent gas equal to the amount of NO gas that would normally be used.

4.2.5.1. T750 Calibrator GPTPS Operation

The following table and figures show the status of the T750's internal pneumatic components and internal gas flow when the instrument is in **GPTPS** generating mode.

Table 4-6: Status of Internal Pneumatics During GENERATE → GPTPS Mode

MODE	VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized					MFCs			PHOT PUMP[3]
	CYL IN	DILUENT IN	GPT	O_3 GEN[2, 3]	*PHOT M/R*[1]	*CAL1*	*CAL2*[1]	DILUENT	
GPTPS	**X**	**O**	**E**	**E**	*Switching*	***OFF***	***OFF***	**ON**	**ON**

[1] Only present if multiple cal gas MFC option is installed.

[2] Present with O_3 generator option.

[3] Present with photometer option.

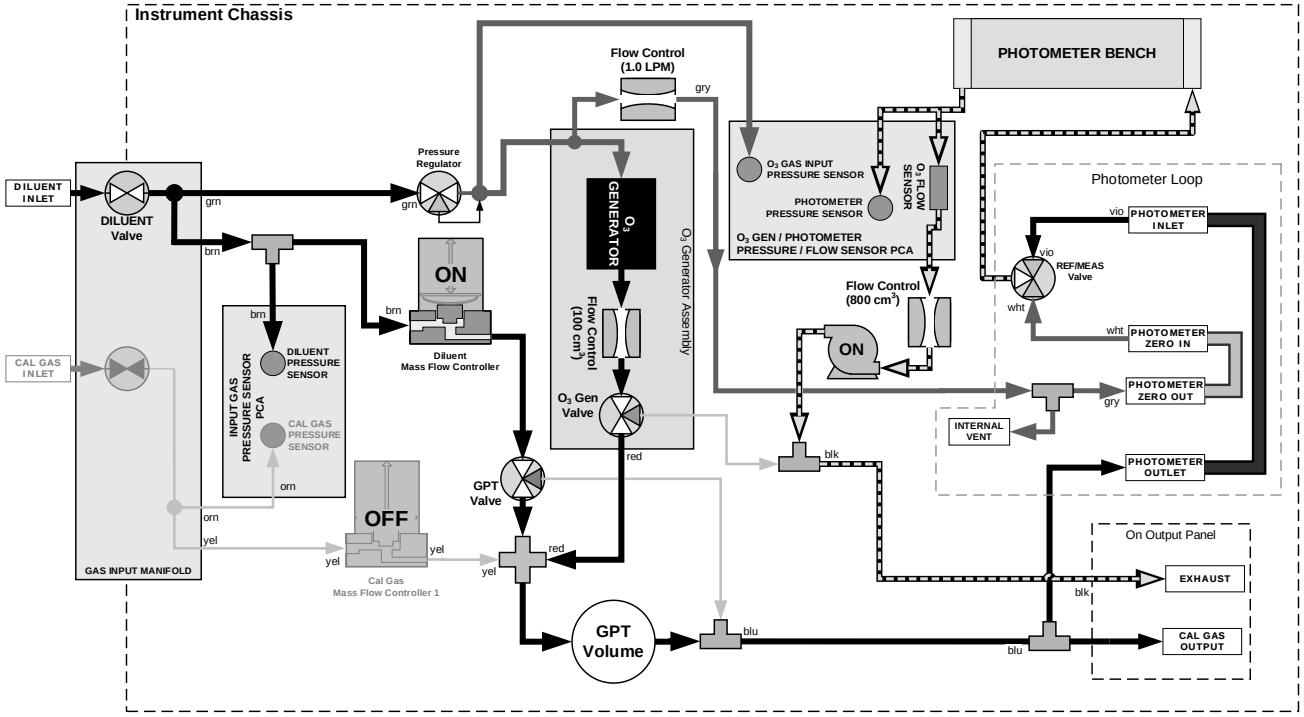


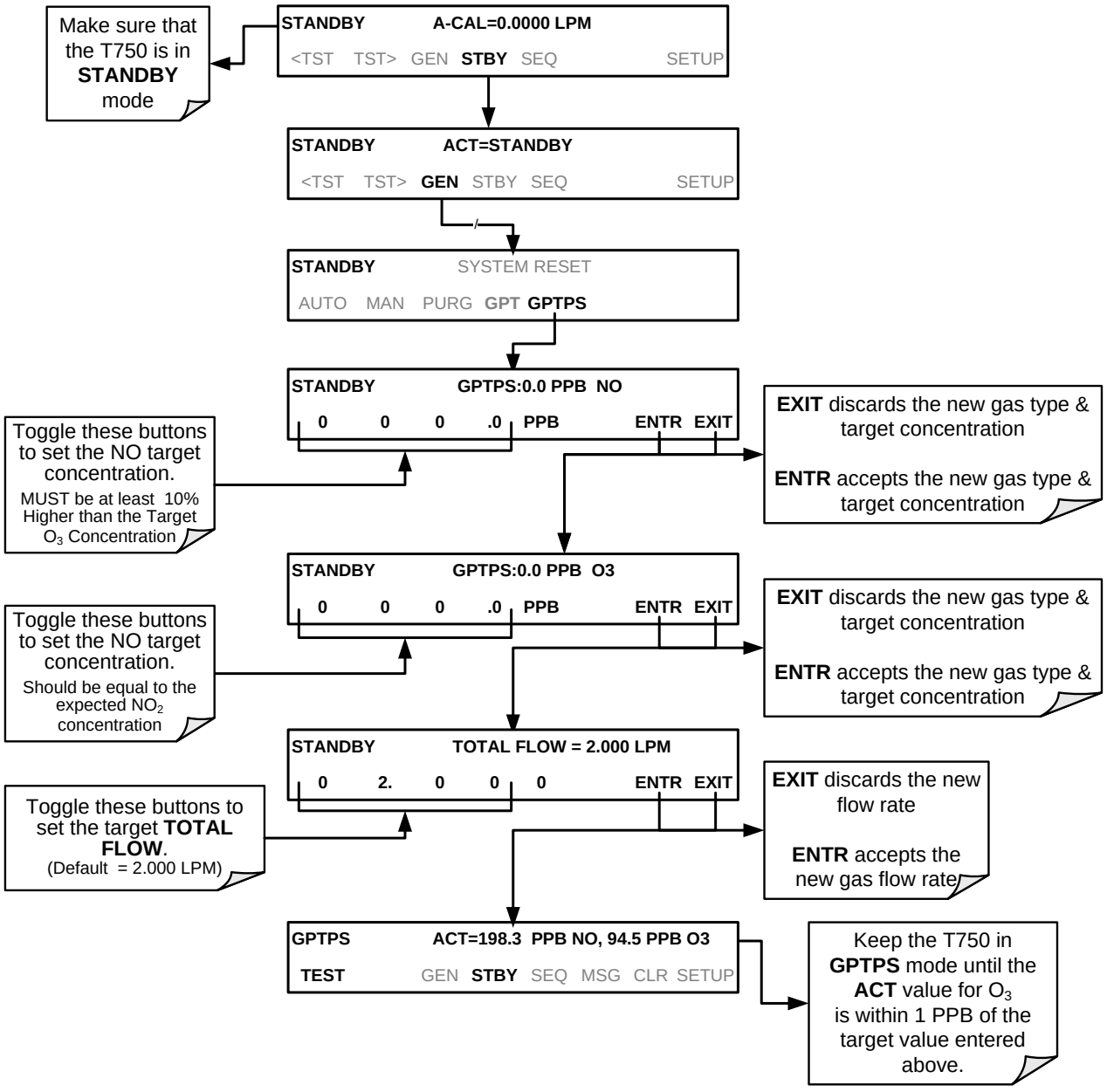
Figure 4-8: Gas Flow through T750 with O_3 Options when in GPTPS Mode

4.2.5.2. **Initiating a GPTPS**

To activate the **GPTPS** feature you will need to know:

- The **TOTAL GAS FLOW** for the mixture output;
- The Target O_3 concentration (equal to the target NO_2 concentration being simulated), and;
- The NO source gas concentration.

Then, press:



4.2.6. GENERATE → GPT: PERFORMING A GAS PHASE TITRATION CALIBRATION

4.2.6.1. T750 Calibrator GPT Operation

The following table and figure show the status of the T750's internal pneumatic components and internal gas flow when the instrument is in **GPT** generating mode.

Table 4-7: Status of Internal Pneumatics During GENERATE → GPT Mode

MODE	VALVES (X = Closed; O = Open) (D = Deenergized; E = Energized)					MFCs			PHOT PUMP[3]
	CYL IN	DILUENT IN	GPT	O_3 GEN[3, 4]	PHOT M/R[1]	CAL1	CAL2[1]	DILUENT	
GPT	O	O	E	E	Reference Phase	ON[2]	ON[2]	ON	OFF

[1] Only present if multiple cal gas MFC option is installed.

[2] In instruments with multiple MFCs, the CPU chooses which MFC to use depending on the target gas flow requested.

[3] Present with photometer option.

[4] Present with O_3 generator option.

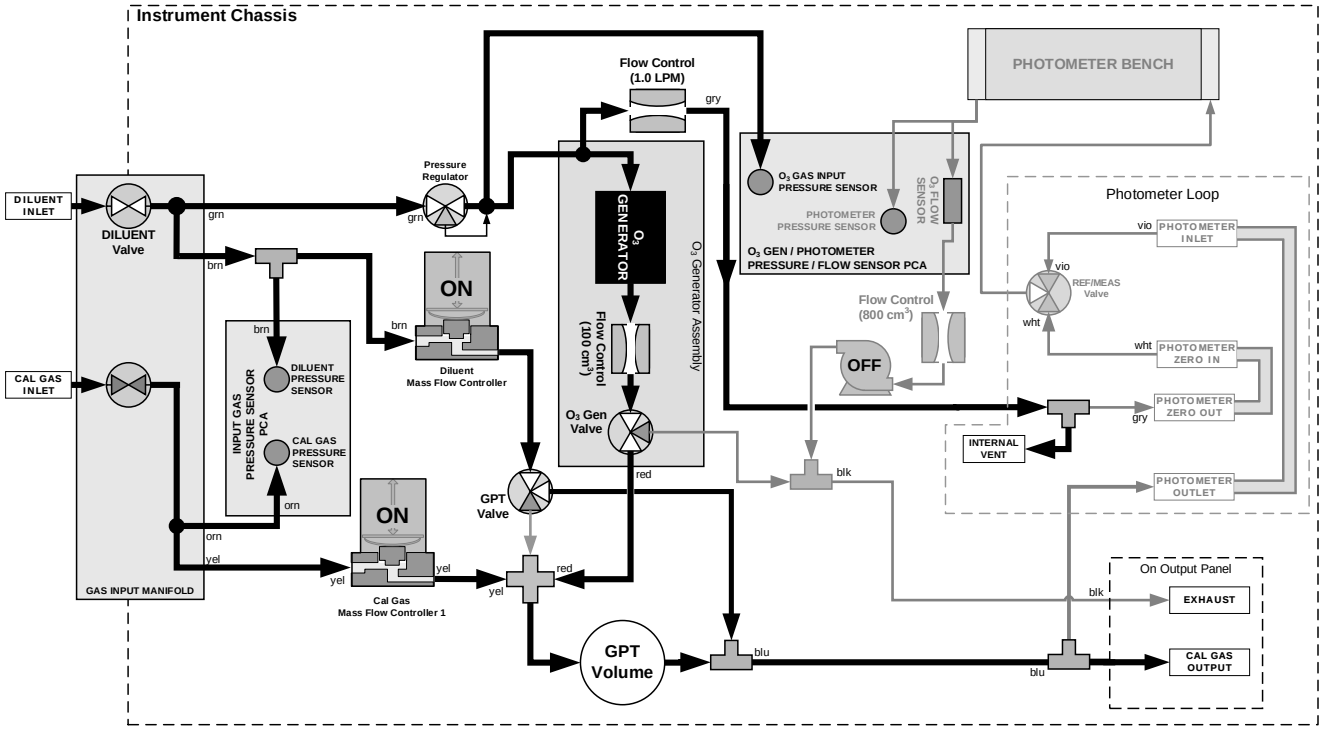


Figure 4-9: Gas Flow through T750 with O_3 Options when in GPT Mode

4.2.6.2. **Initiating a GPT Calibration Gas Generation**

IMPORTANT

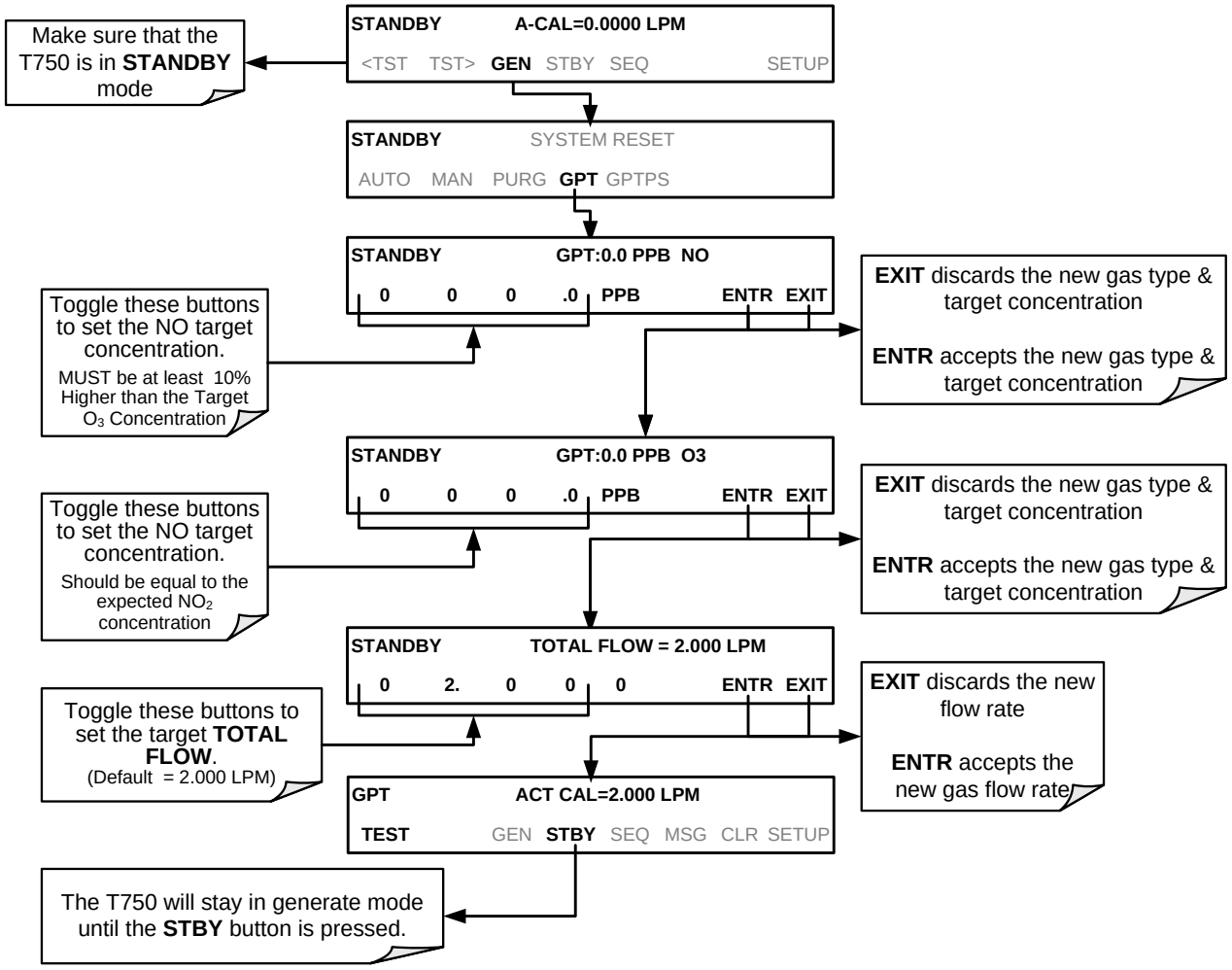
IMPACT ON READINGS OR DATA

it is required that a GPT Pre-Set (GPTPS, Section 4.2.4) be performed before initiating any GPT gas generation.

To initiate GPT gas generation you will need to know:

- The **TOTAL GAS FLOW** for the mixture output;
- The Target O_3 concentration (equal to the target NO_2 concentration to be generated), and;
- The NO source gas concentration.

Then, press:

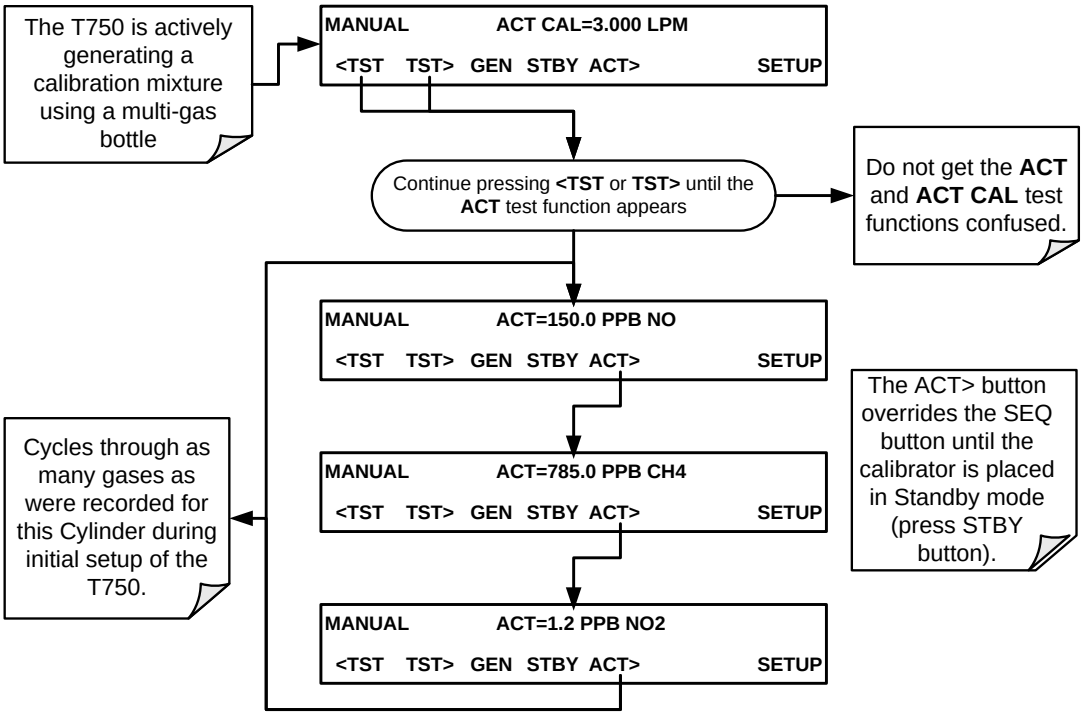


4.2.7. GENERATE →ACT: VIEWING CONCENTRATIONS GENERATED FROM MULTI-GAS CYLINDERS

When a concentration mixture is being generated, using a multiple-gas cylinder as a source the software uses the Diluent and Cal gas flow rates to calculate the actual concentration for each gas in the cylinder so that it is possible to see the concentrations of all of the gases being output by the T750 calibrator.

EXAMPLE: For a cylinder containing a blend of CH_4, NO and NO_2, a common contaminant is present in small quantities in bottles containing NO: This will display the actual concentration being generated for each gas in the multiple-gas cylinder.

When generating a concentration of one of the two primary gases in the cylinder (e.g. NO or CH4) using the GEN → AUTO, GEN → MANUAL buttons or a preprogrammed calibration SEQUENCE, press:



Note

The ACT button only appears if the T750 is generating gas from a multiple-gas cylinder. To start any preprogrammed calibration SEQuences, first place the calibrator in STANDBY mode (the SEQ button replaces the ACT button)

For NO cylinders, the instrument will only display the amount of NO_2 in the calibration mixture if the concentration of NO_2 present in the bottle is known and was programmed into the bottle's definition (see Section 3.5.7).

4.2.7.1. Using the T750 Calibrator as an O_3 Photometer

If the T750 calibrator is equipped with the optional O_3 photometer the **ACT** test function allows it to be used as an O_3 photometer to measure external sources of O_3.

4.3. AUTOMATIC CALIBRATION SEQUENCES

The T750 calibrator can be set up to perform automatic calibration sequences of multiple steps. These sequences can perform all of the calibration mixture operations available for manual operation and can be initiated by one of the following methods:

- LCD touchscreen buttons
- internal timer,
- external digital control inputs
- RS-232 interface
- Ethernet interface
- sub-processes in another sequence

4.3.1. SETUP → SEQ: PROGRAMMING CALIBRATION SEQUENCES

A sequence is a set of steps where each is an instruction that causes the instrument to perform an operation. These steps are grouped under a user defined SEQUENCE NAME.

For each sequence, there are seven attributes to be programmed, which are listed in Table 4-8.

Table 4-8: Automatic Calibration SEQUENCE Set-Up Attributes

ATTRIBUTE	DESCRIPTION
NAME	Allows the user to create a text string of up to 10 characters identifying the sequence.
REPEAT COUNT	Number of times, between 0 and 100, to execute the same sequence. A value of 0 (zero) causes the sequence to execute indefinitely.
CC INPUT	Specifies which of the T750's Digital Control Inputs will initiate the sequence.
CC OUTPUT	Specifies what device the T750's Digital Control Outputs will be sent to when the sequence is active.
TIMER ENABLE	Enables or disables an internal automatic timer that can initiate sequences and set the duration between repetitions, using the T750's built in clock.
STEPS	A series of submenus for programming the activities and instructions that make up the calibration sequence.
PROGRESS MODE	Allows the user to select the reporting style the calibrator uses to report the progress of the sequences on the display screen, as it runs.

The more common instruction steps available for creating calibration sequences are listed in Table 4-9.

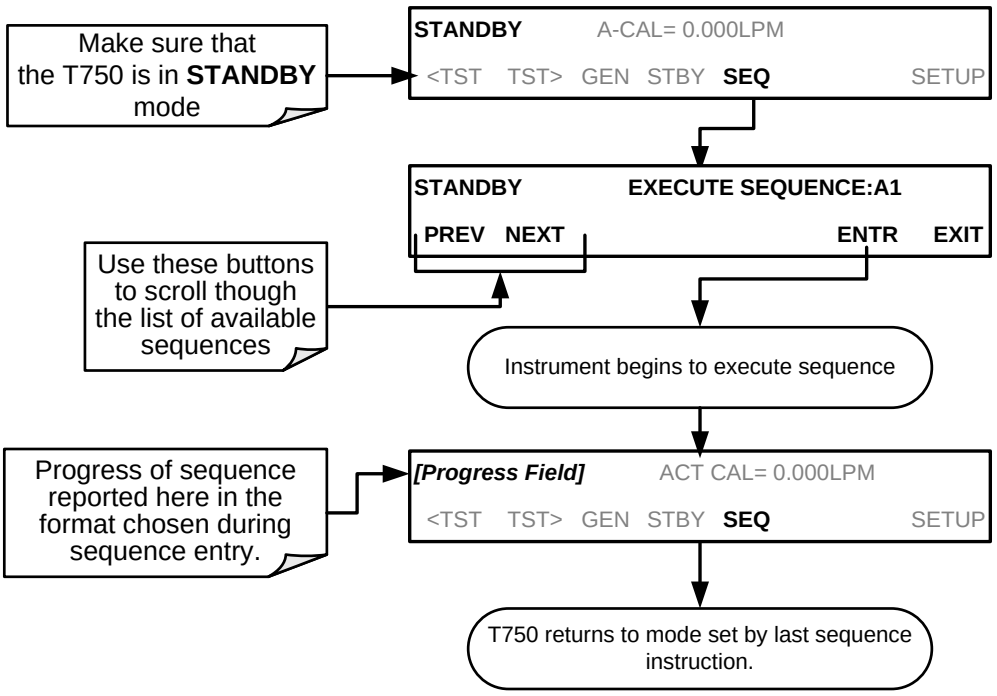
Table 4-9: Calibration SEQUENCE Step Instruction

INSTRUCTION NAME	DESCRIPTION
GENERATE	Puts the instrument into **GENERATE** mode. Similar in operation and effect to the **GENERATE → AUTO** function used at the LCD touchscreen.
DURATION	Adds a period of time between the previous instruction and the next
STANDBY	Places the instrument in STANDBY mode, and should be followed by DURATION in order to keep the sequence running rather than idling.
GPT	Initiates a Gas Phase Titration operation (available with O_3 Gen and Photometer option)
EXECSEQ	Nests an existing sequence to be executed at this point before advancing to the next step once the called sequence is completed. Up to 5 levels of nested sequences can be programmed.
SETCCOUTPUT	Allows the sequence to activate the T750's digital control outputs. Similar to the CC OUPUT attribute, but can be set and reset by individual steps.
MANUAL	Puts the instrument into **GENERATE** mode. Similar in operation and effect to the **GENERATE → MAN** function used at the LCD touchscreen.

To create a sequence, use the instructions in the following sections to name the sequence, set its associated parameters and define the steps to be included.

4.3.1.1. **Activating a Sequence from the T750 LCD Touchscreen**

To activate an already programmed sequence from the LCD touchscreen, press:

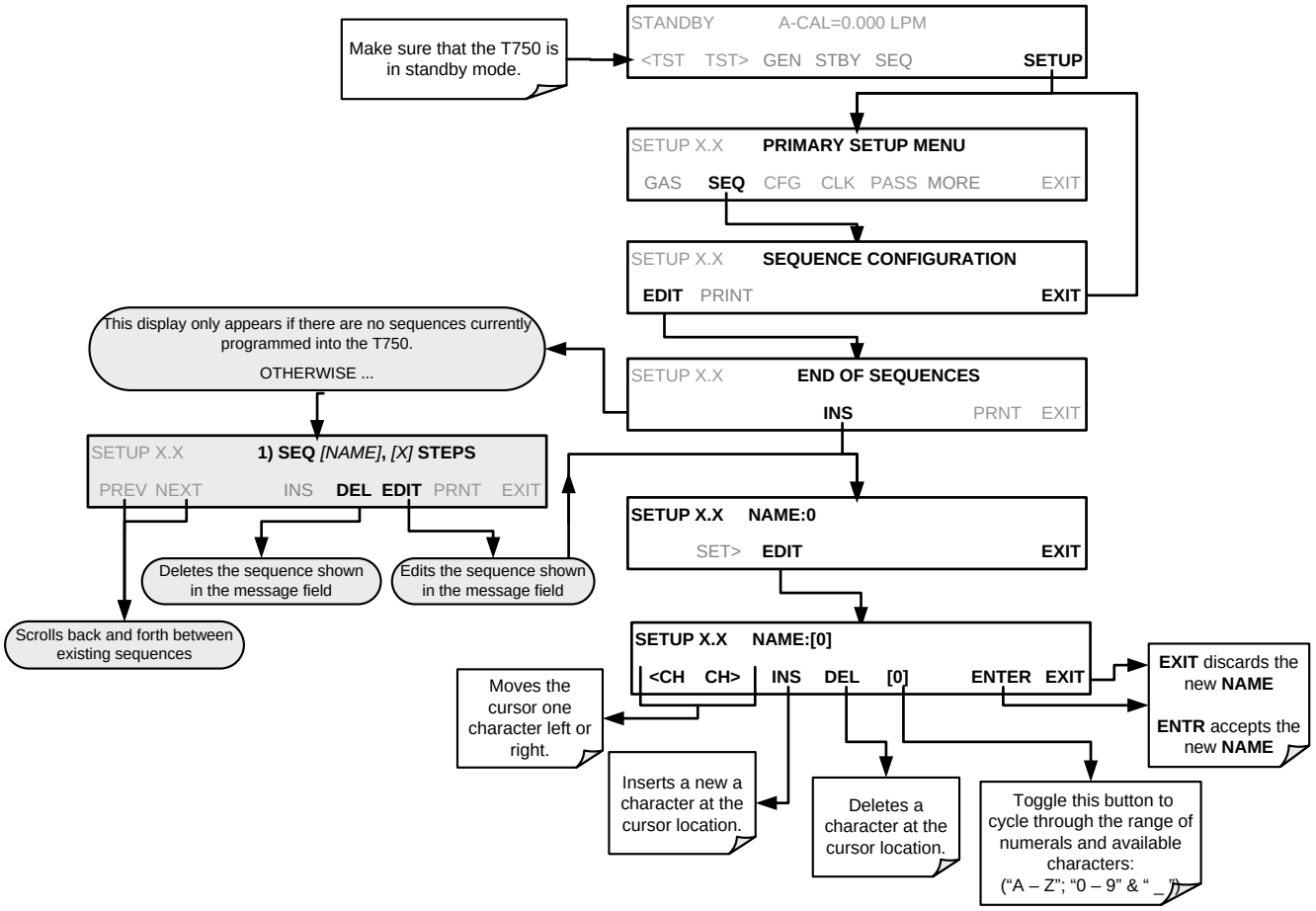


4.3.1.2. **Sequence Name**

The first step of creating a calibration sequence is to assign it a name. The name can be up to 10 characters and can be comprised of any alpha character (A to Z), and numeral (0 to 9) or the underscore character ("_").

Note **All sequences should be assigned a unique name.**

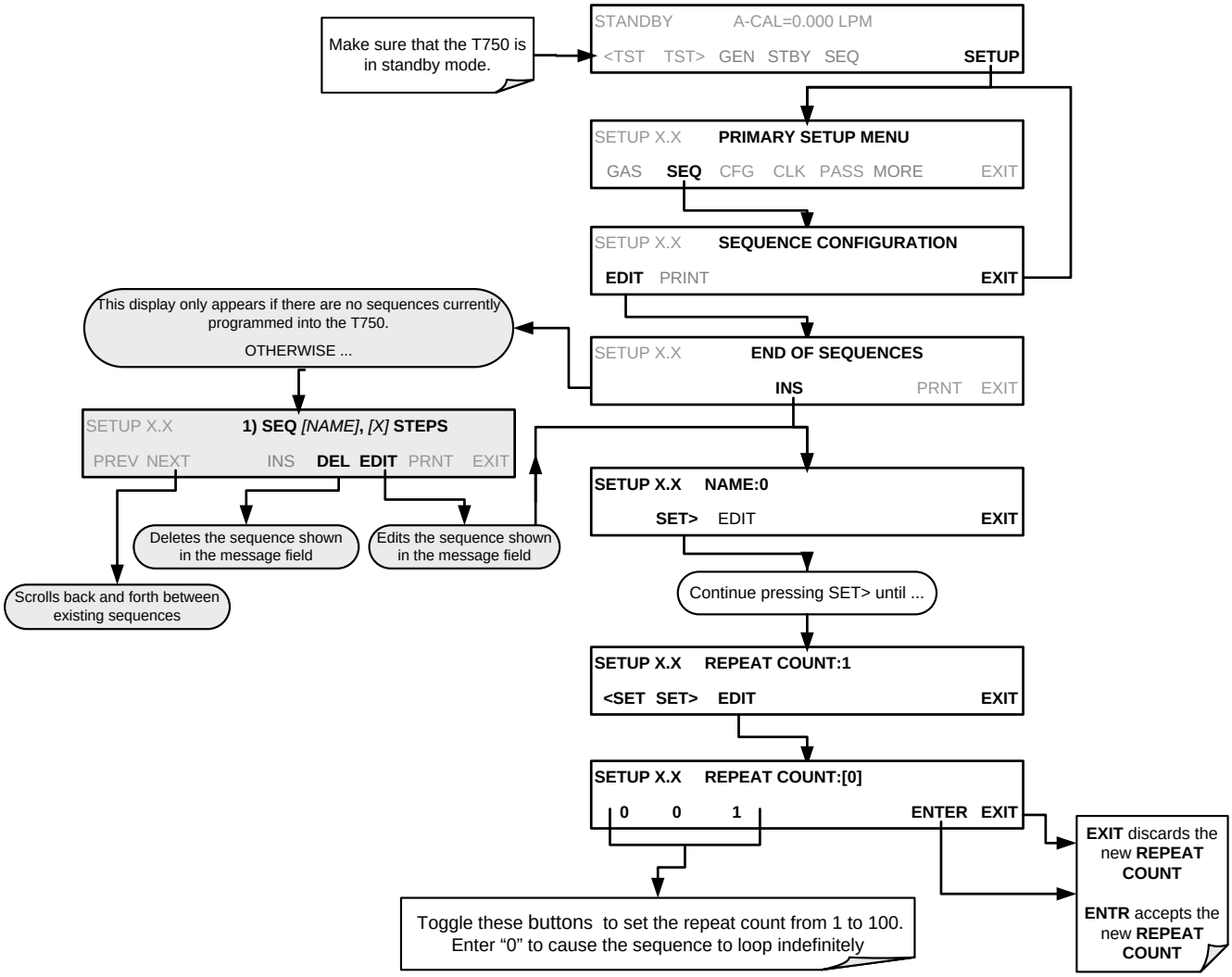
To assign a name to a sequence, press:



4.3.1.3. **Sequence Repetition Counter**

The sequence can be set to repeat a certain number of times, from 1 to 100. It can also be set to repeat indefinitely by inputting a zero (0) into the **REPEAT COUNTER**.

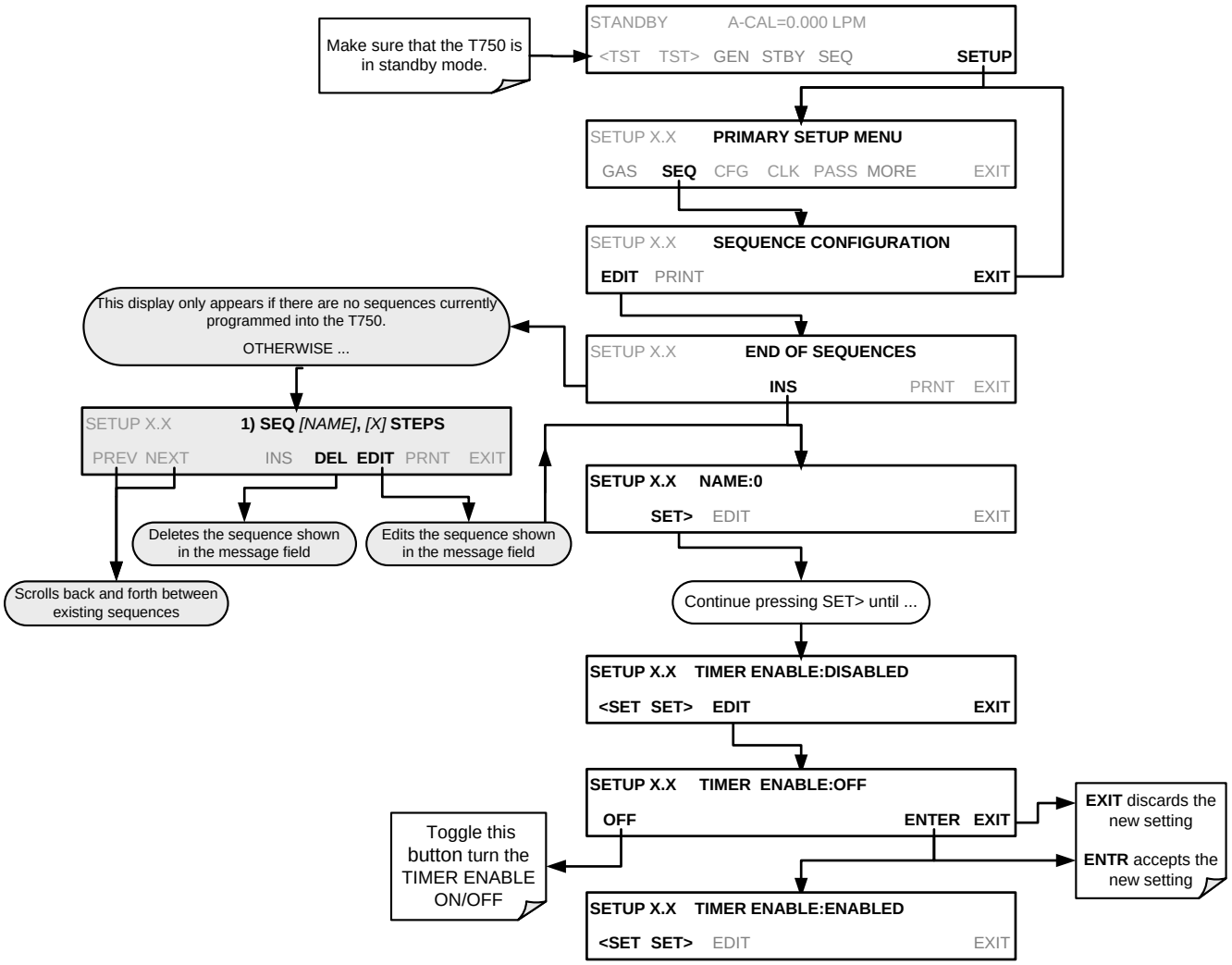
To set the **REPEAT COUNTER**, press:



4.3.1.4. **Sequence Trigger Date/Time and Repetition Delay**

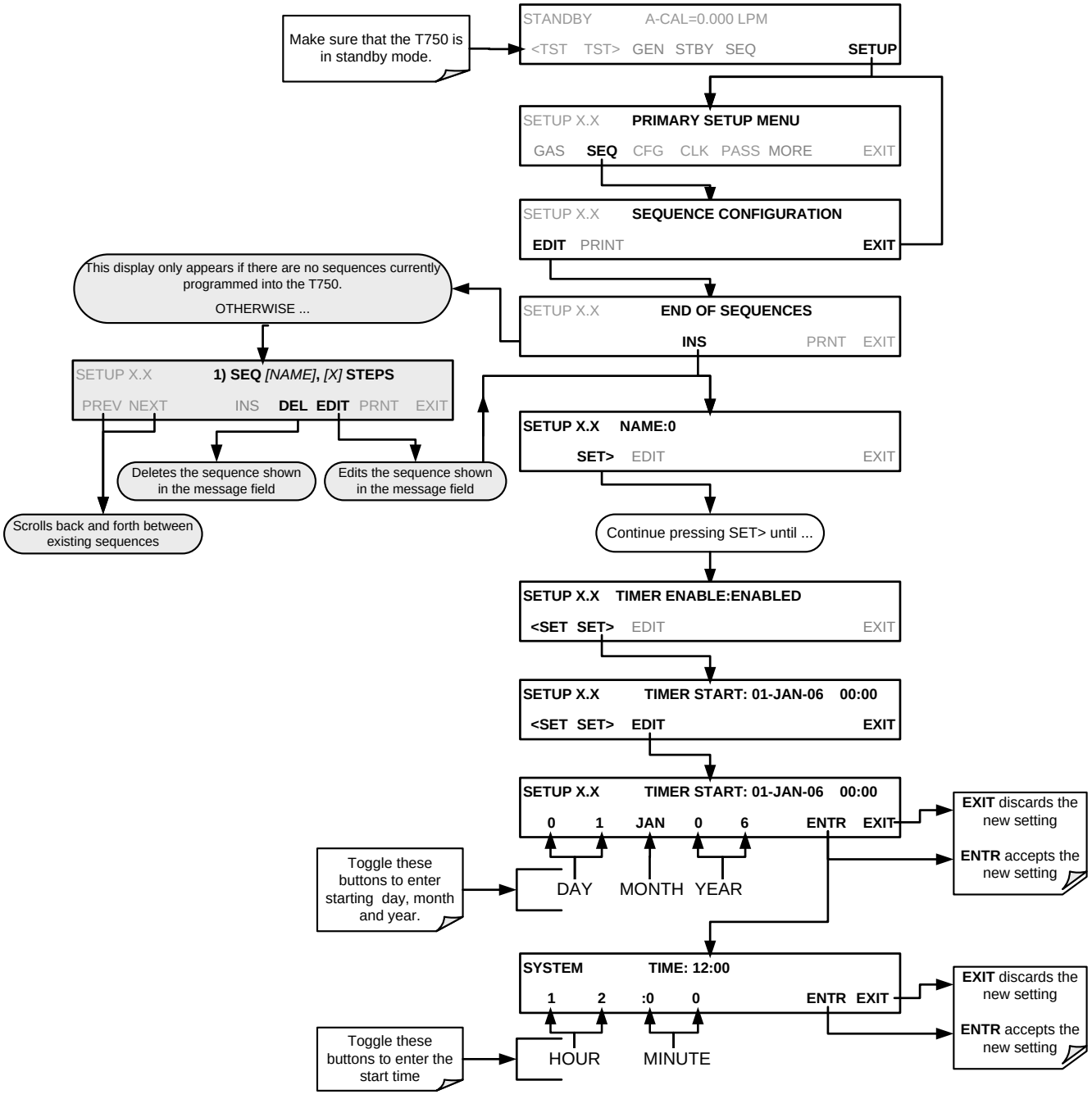
Sequences can be triggered by the instrument's internal clock. Set the sequence to start at a predetermined date and time and, if desired, to repeat after a predetermined delay time.

So activate and sequence timer, press:



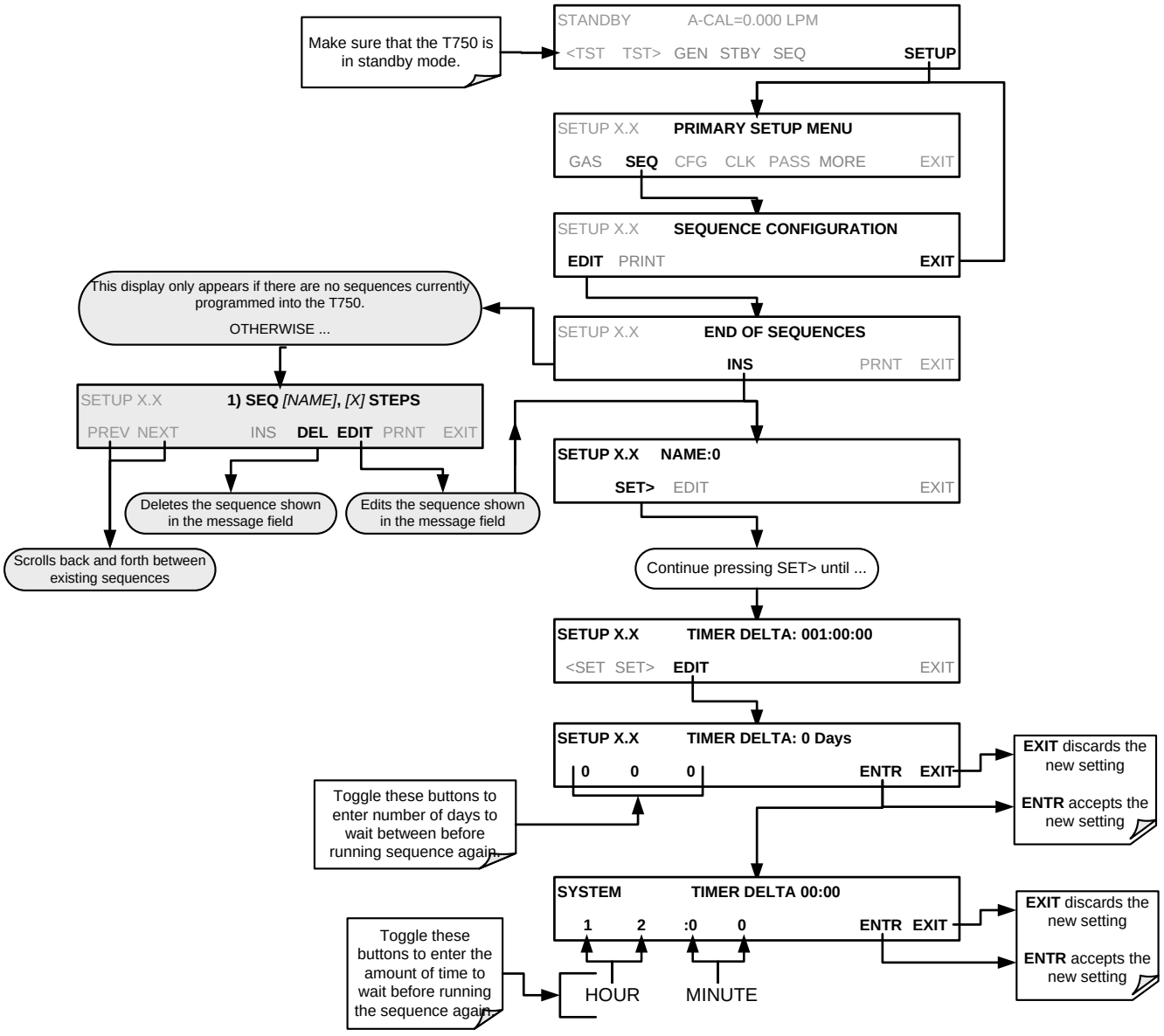
After enabling the timer, set the start (trigger) date and time.

To specify a starting date and time for the sequence, press:



Note **When the start time is set for a date/time that has passed, the sequence will properly calculate the next run time based on that past date/time.**

To set the delta timer for duration of delay between repetitions (when TIMER is ENABLED), press:



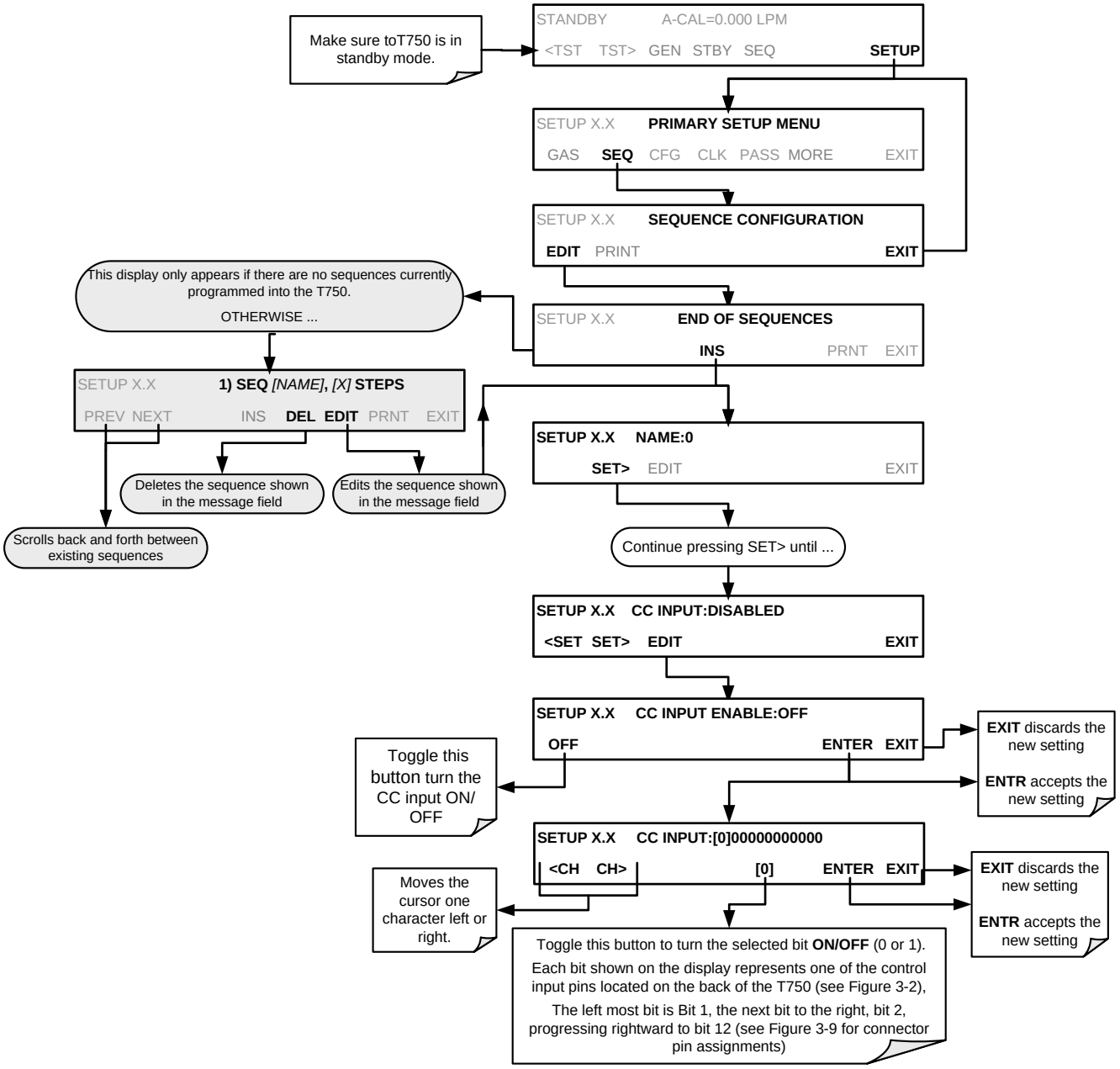
4.3.1.5. **Sequence External Control Inputs (CC INPUT)**

The T750 calibrator's control inputs allow the entire sequence to be triggered from an external source. This feature allows the calibrator to operate in a slave mode so that external control sources, such as a data logger can initiate the calibration sequences.

Each of the T750 calibrator's control outputs is located on the communications and output panel (see Figure 3-5).

- 12 separate ON/OFF switches assigned to separate calibration sequences, or
- A 12-bit wide bus allowing the user to define activation codes for up to 4095 separate calibration sequences

To assign a **CC INPUT** pattern/code to a particular sequence, press:



4.3.1.6. **Sequence Control Outputs to a Device (CC Output)**

Control outputs allow the calibrator to control devices that accept logic-level digital inputs, such as programmable logic controllers (PLCs), data loggers, or digital relays/valve drivers.

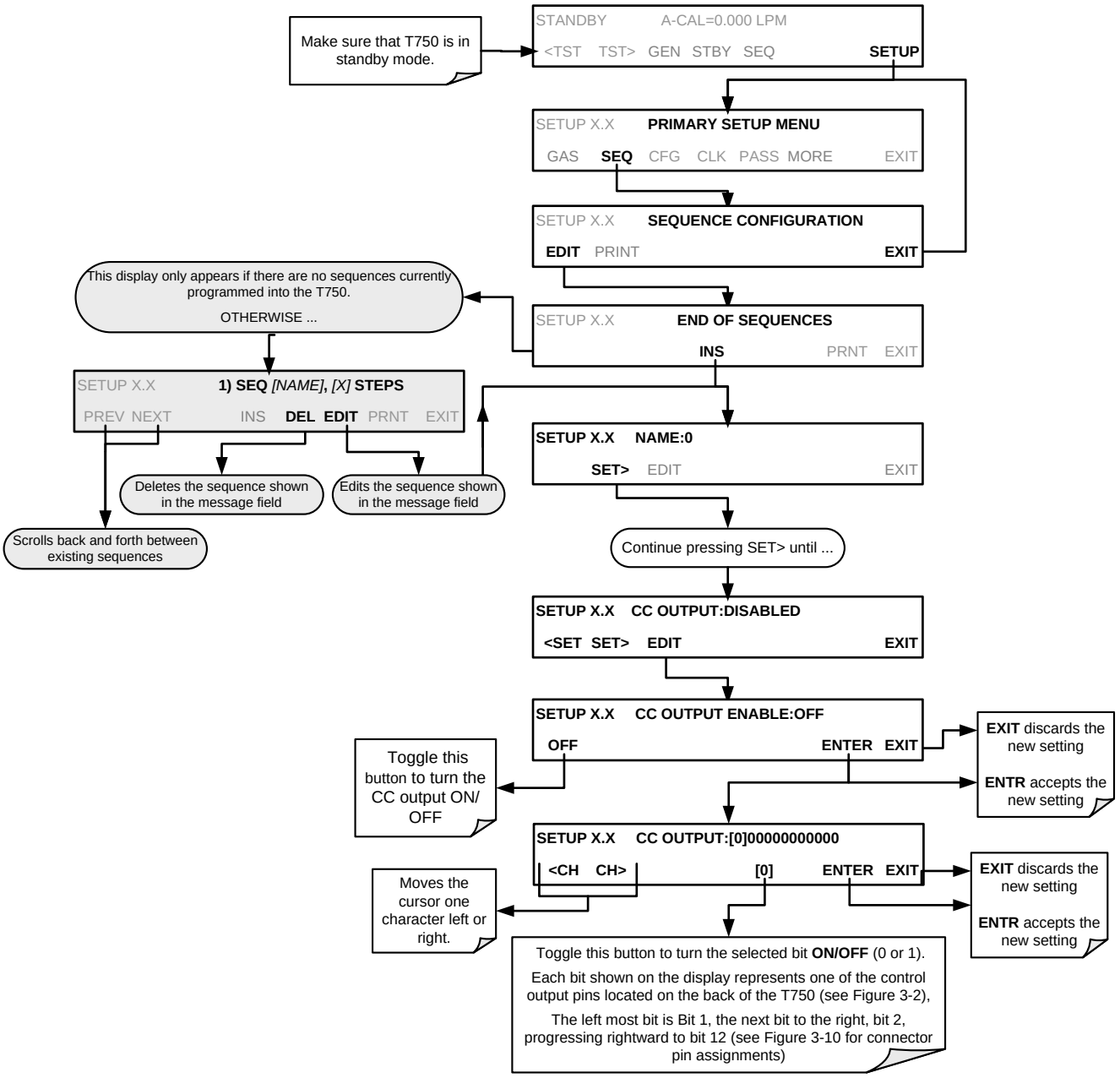
They can be used as:

- 12 separate ON/OFF switches assigned to separate calibration sequences, or;
- A 12-bit wide bus allowing the user to define activation codes for up to 4095 separate calibration sequences.

They can be set to:

- Be active whenever a particular calibration sequence is operating, or;
- Activate/deactivate as individual steps within a calibration sequence are run (see Section 4.3.2.4).

To assign a **CC OUTPUT** pattern/code to a particular sequence, press:


Make sure that T750 is in standby mode.
STANDBY A-CAL=0.000 LPM
<TST TST> GEN STBY SEQ SETUP
SETUP X.X PRIMARY SETUP MENU
GAS SEQ CFG CLK PASS MORE EXIT
SETUP X.X SEQUENCE CONFIGURATION
EDIT PRINT EXIT
This display only appears if there are no sequences currently programmed into the T750.
OTHERWISE ...
SETUP X.X END OF SEQUENCES
INS PRNT EXIT
SETUP X.X 1) SEQ [NAME], [X] STEPS
PREV NEXT INS DEL EDIT PRNT EXIT
Deletes the sequence shown in the message field
Edits the sequence shown in the message field
Scrolls back and forth between existing sequences
SETUP X.X NAME:0
SET> EDIT EXIT
Continue pressing SET> until ...
SETUP X.X CC OUTPUT:DISABLED
<SET SET> EDIT EXIT
SETUP X.X CC OUTPUT ENABLE:OFF
OFF ENTER EXIT
Toggle this button to turn the CC output ON/ OFF
EXIT discards the new setting
ENTR accepts the new setting
SETUP X.X CC OUTPUT:[0]00000000000
<CH CH> [0] ENTER EXIT
Moves the cursor one character left or right.
EXIT discards the new setting
ENTR accepts the new setting
Toggle this button to turn the selected bit ON/OFF (0 or 1).
Each bit shown on the display represents one of the control output pins located on the back of the T750 (see Figure 3-2),
The left most bit is Bit 1, the next bit to the right, bit 2, progressing rightward to bit 12 (see Figure 3-10 for connector pin assignments)

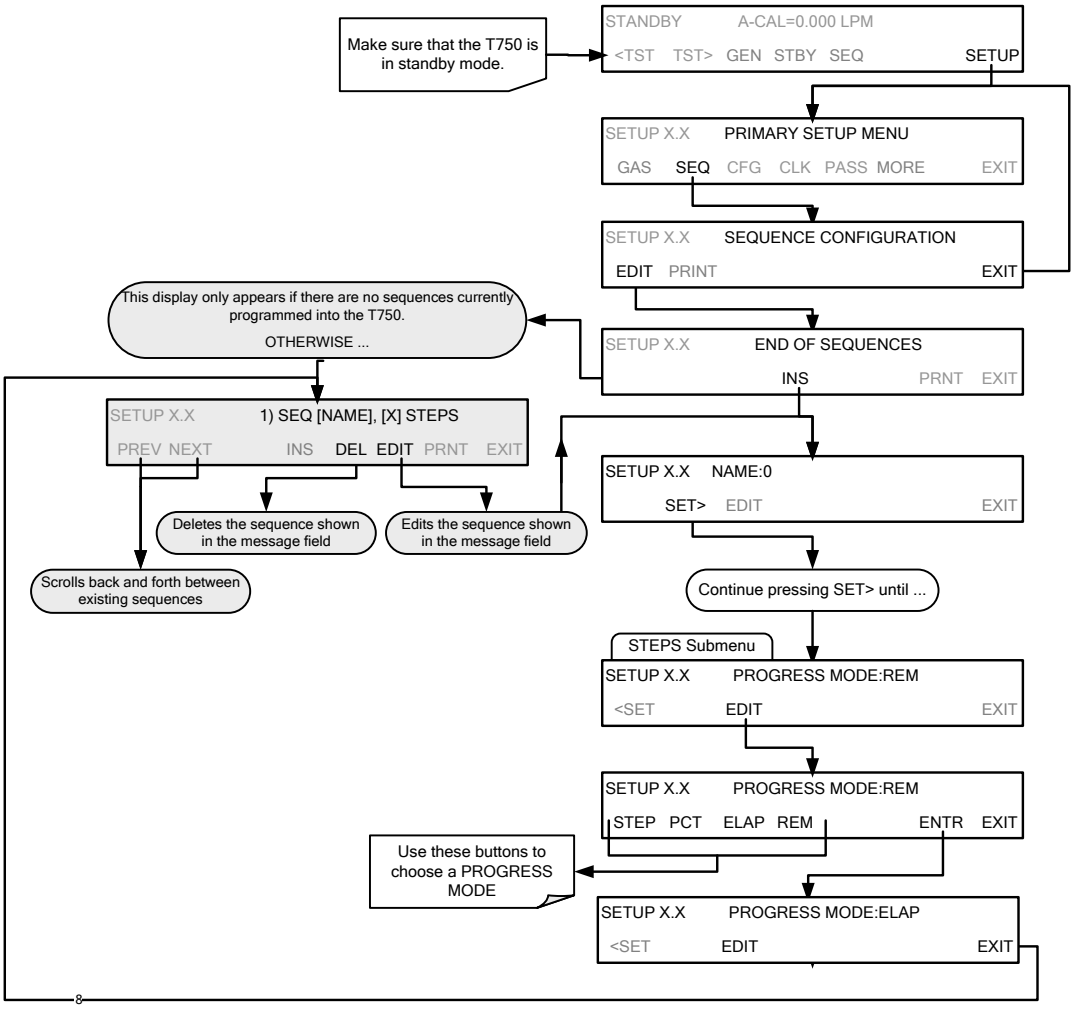
4.3.1.7. **Sequence PROGRESS Reporting Mode**

As sequences run, the T750 calibrator reports progress by displaying a message in the MODE field of the display (See Figure 3-1). There are several types of report modes available (see Table 4-10).

Table 4-10: Sequence Progress Reporting Mode

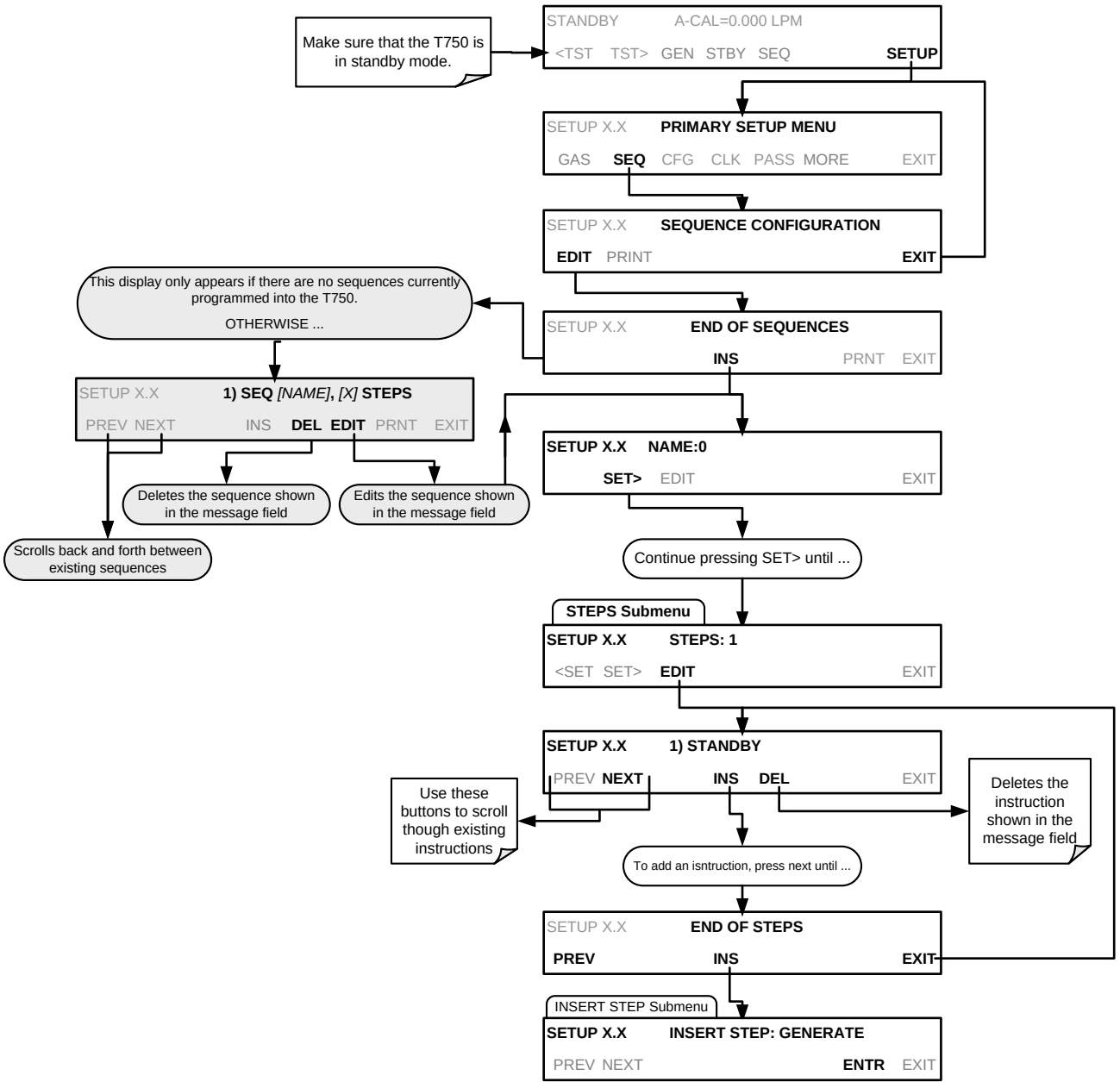
MODE	DESCRIPTION
STEP	Shows the progress as the sequence name and step number. This is the traditional display. Example: Progress for a sequence named "SO2_Test" would appear as "SO2_Test-2", indicating that it is currently executing step 2.
PCT	Shows the progress as a percent (0–100%) of each duration step. Example: "SEQ 48%"
ELAP	Shows the progress as time elapsed in hours, minutes and seconds, counting upward from 0. Example: "T+01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds have elapsed)
REM	Shows the progress as time remaining in hours, minutes, and seconds remaining, counting downward to 0. Example: "T-01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds are remaining)

To select a PROGRESS report mode, press:



4.3.2. **ADDING SEQUENCE STEPS**

To insert an instruction step into a sequence, navigate to the **INSERT STEP** submenu by pressing:

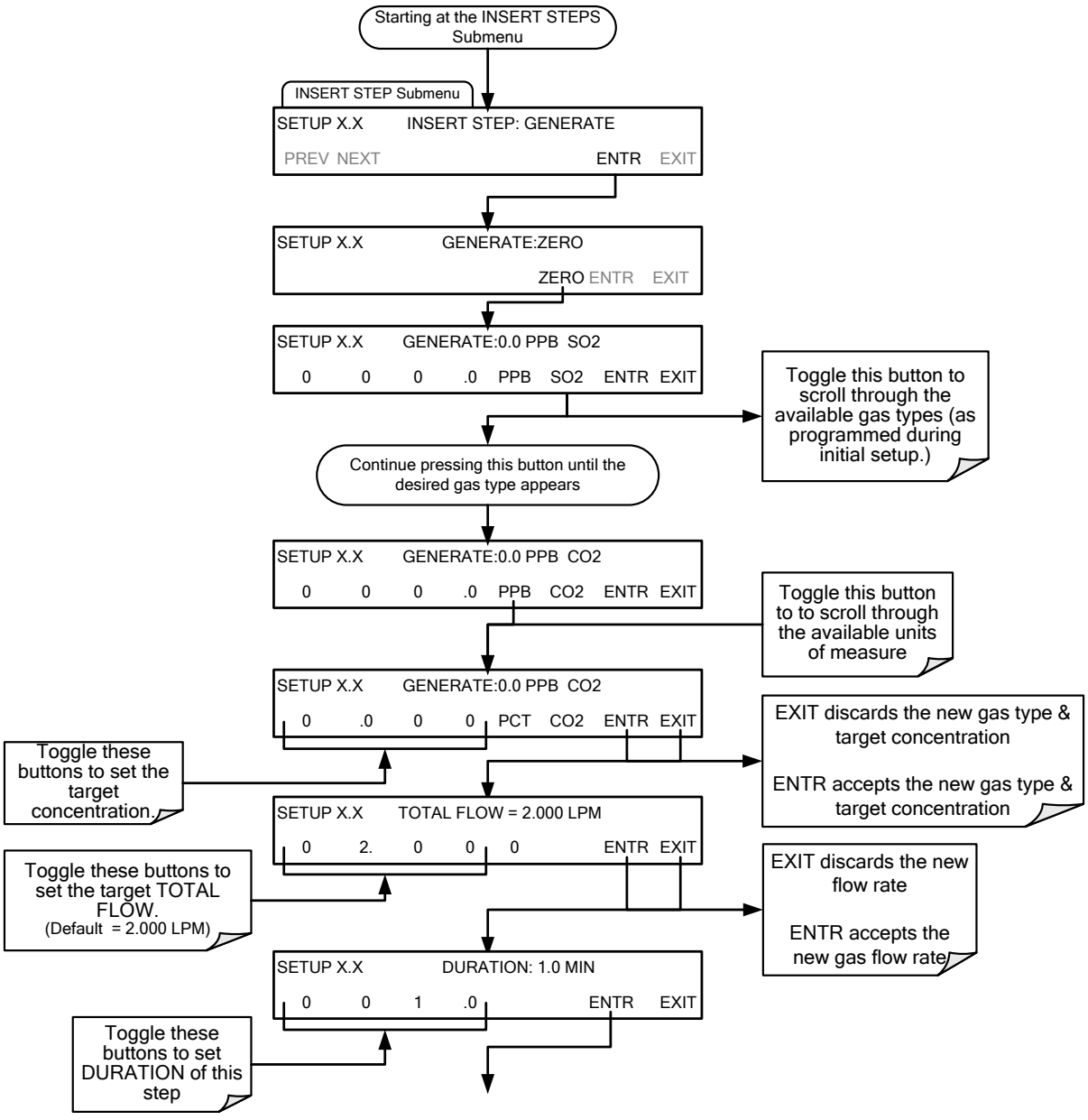


4.3.2.1. **The GENERATE Step**

This step operates and is programmed similarly to the **GENERATE → AUTO** menu.

At the end of the programming sequence, the T750 firmware will automatically insert a **DURATION** step that needs to be defined.

To insert a **GENERATE** step into a sequence, press:



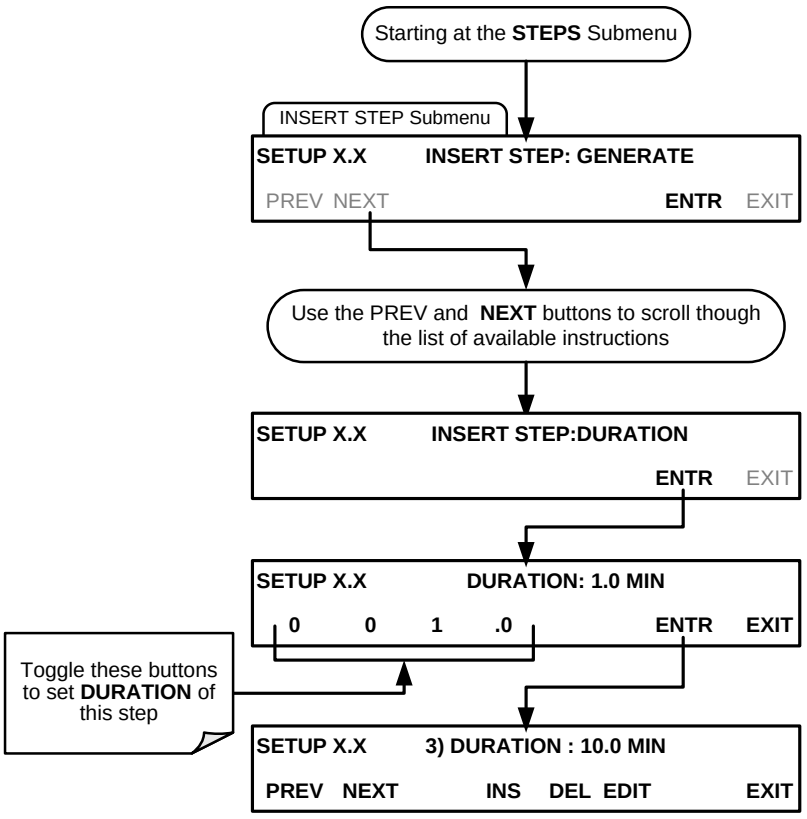
Note **If the user attempts to generate a source gas type that has not been entered into the T750's gas library, the sequence will freeze and after a certain time-out period, stop running.**

4.3.2.2. **The DURATION Step**

The duration step causes the T750 to continue performing whatever action was called for by the preceding step of the sequence.

- If that step put the instrument into **STANDBY** mode, the calibrator stays in **STANDBY** mode for the period specified by the **DURATION** step,
- If that step put the instrument into **GENERATE** mode, the will continue to **GENERATE** whatever calibration mixture was programmed into that step for the period specified by the **DURATION** step.

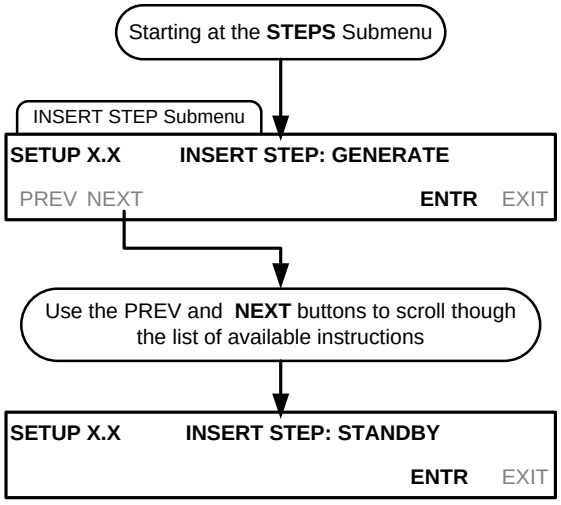
To insert a **DURATION** step into a sequence, press:



4.3.2.1. **The STANDBY Step**

The **STANDBY** step places the T750 into **STANDBY** mode. It is recommended, but not required to follow this with a **DURATION** step.

To insert a **STANDBY** step into a sequence, press:

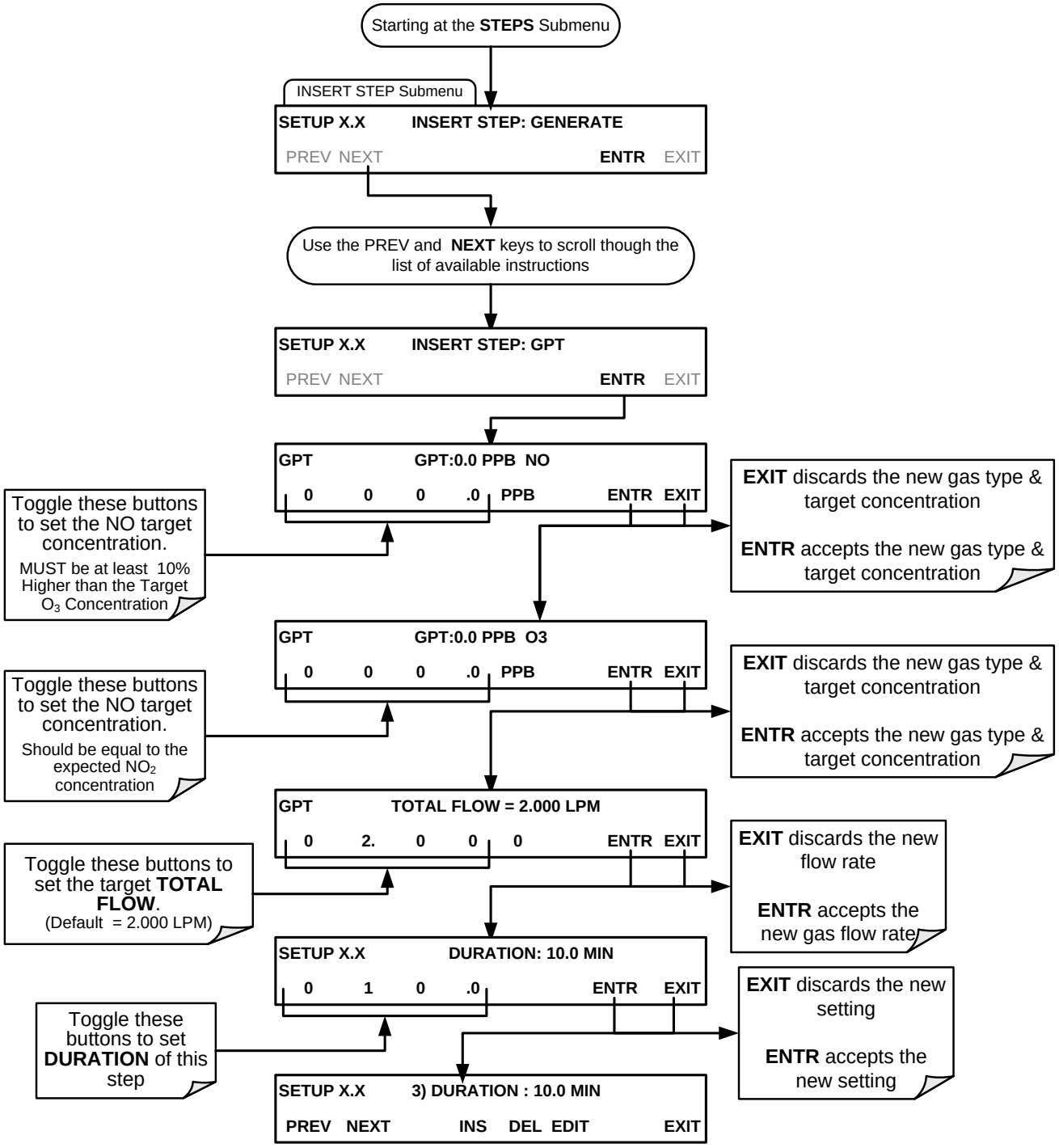


4.3.2.2. **The GPT Step**

See Section 4.2.3 for information on choosing the correct input values for this step**.**

At the end of the programming sequence, the T750 firmware will automatically insert a **DURATION** step that needs to be defined.

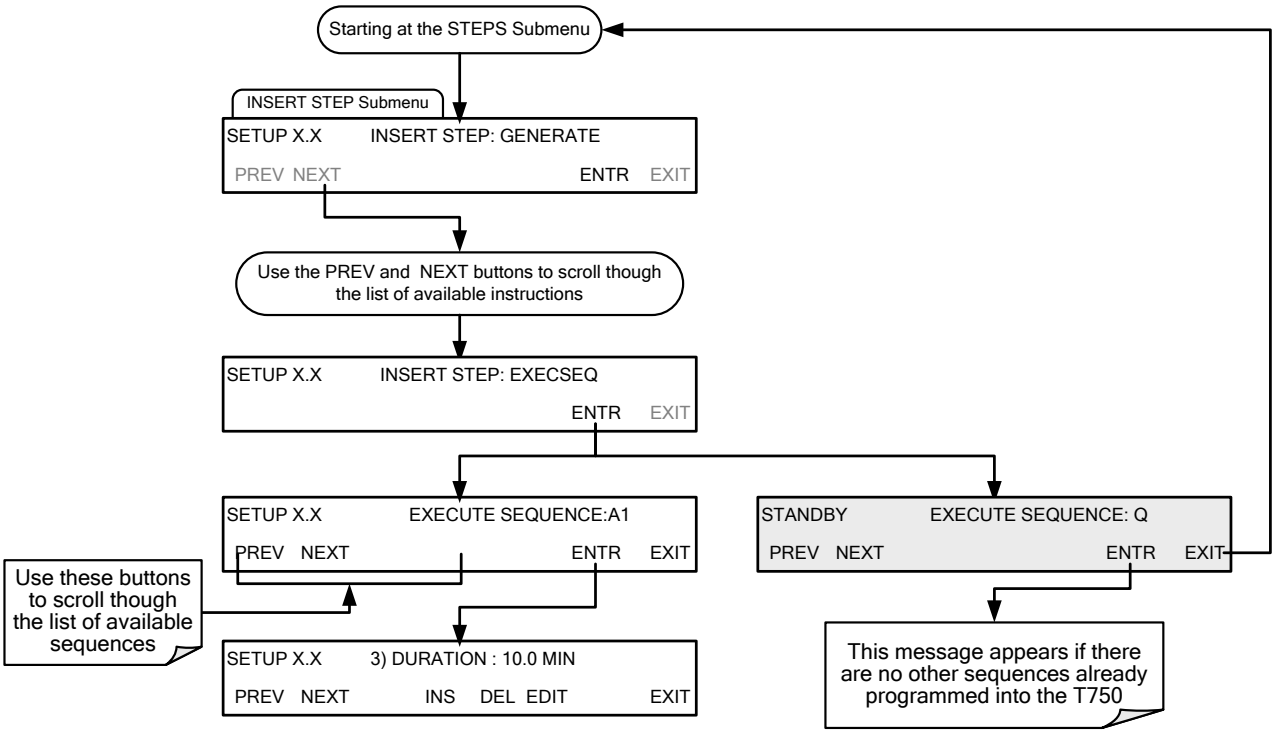
To insert a **GPT** step into a sequence, press:



4.3.2.3. **The EXECSEQ Step**

The **EXECSEQ** step allows the sequence to call another, already programmed sequence to be nested between steps. This is a very powerful tool in that it allows the user to create a "toolbox" of often-used operations that can then be mixed and matched by an overhead sequence.

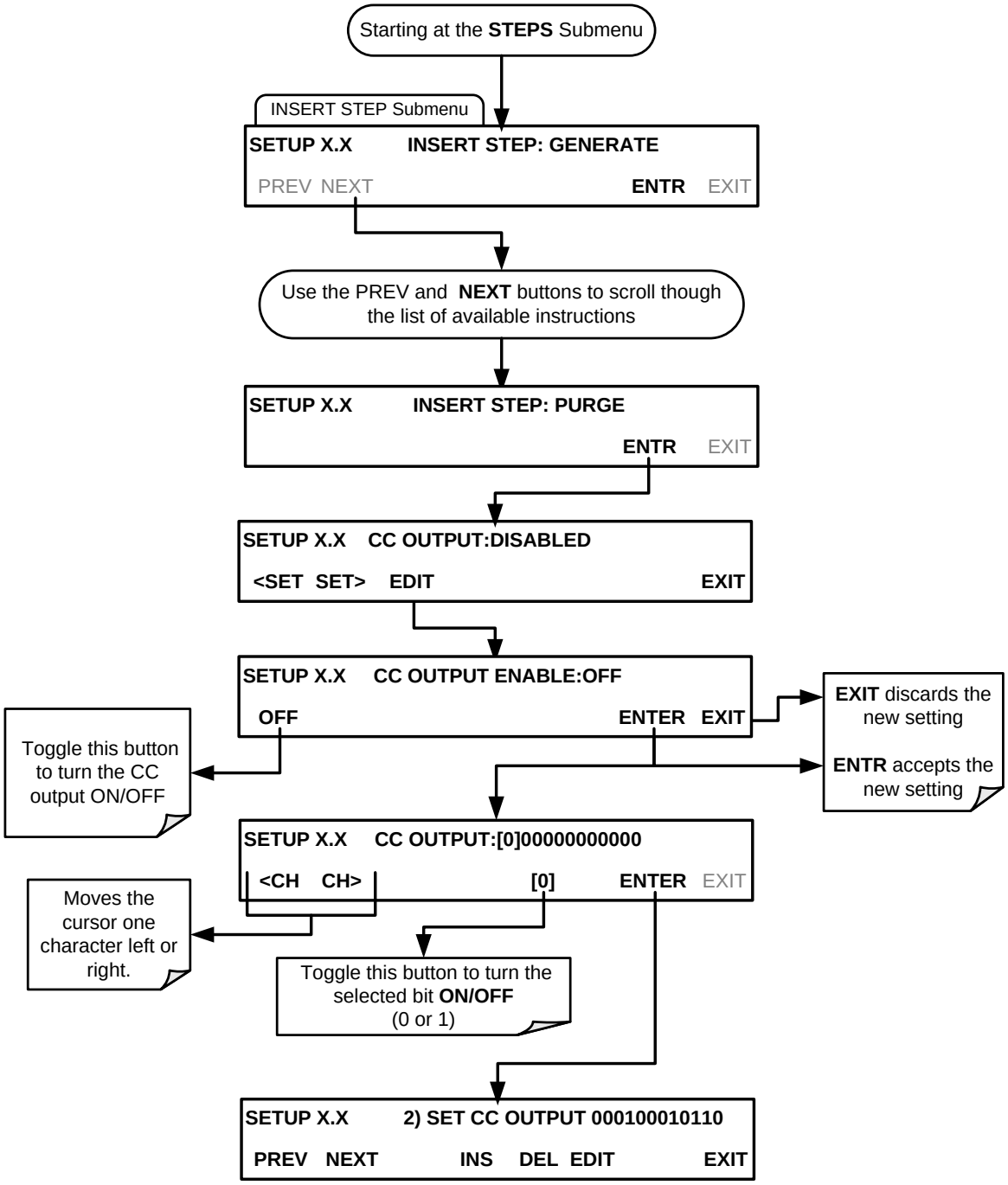
To insert an **EXECSEQ** step into a sequence, press:



4.3.2.4. **The SET CC OUTPUT Step**

This instruction causes the sequence to set or reset the T750's digital control outputs. It is very useful in situations where the control outputs are being used to trigger other devices that need to be turned off and on in synch with the operation of the calibrator as it progress through the sequence.

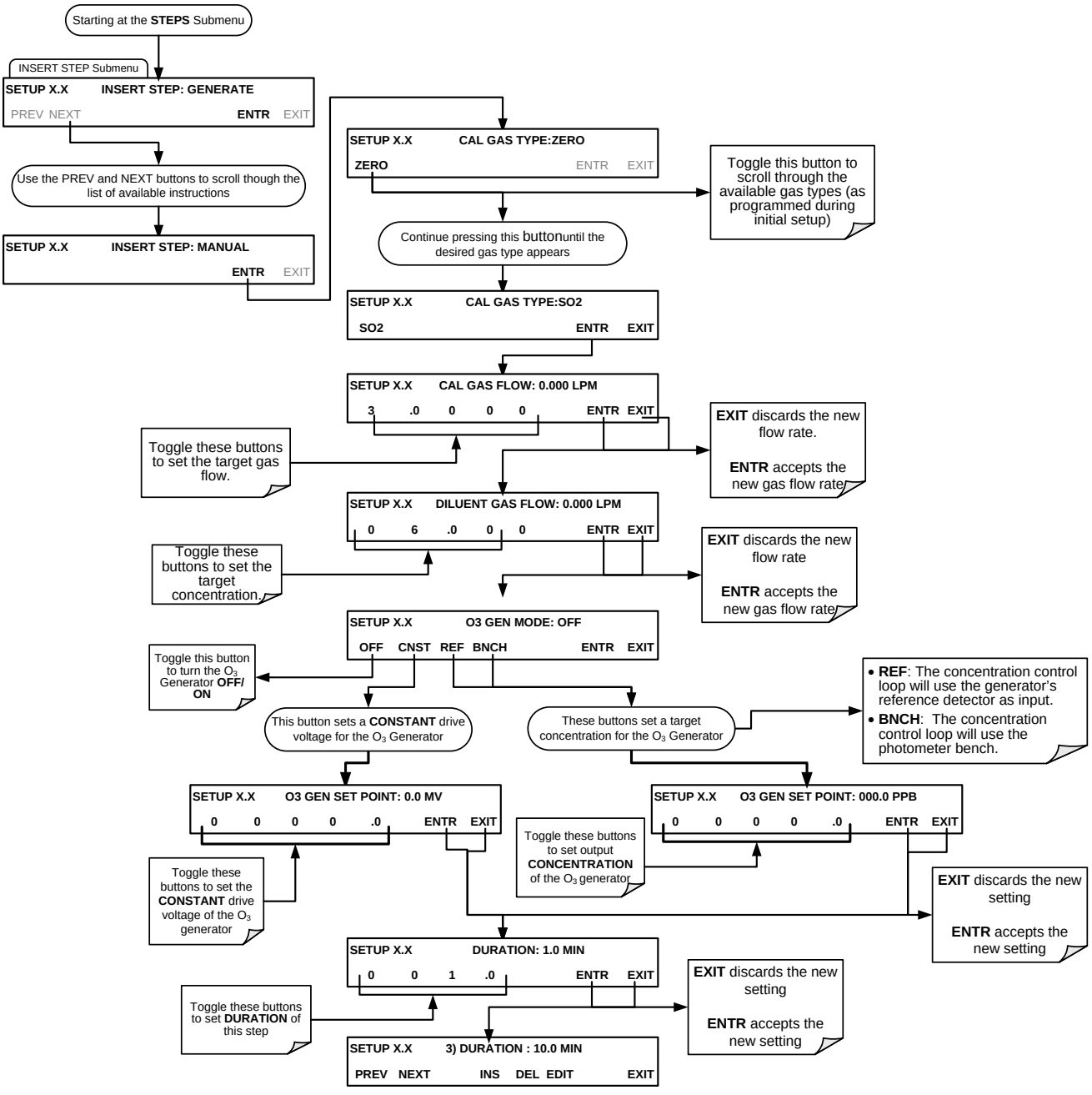
To insert a **CC OUTPUT** step into a sequence, press:



4.3.2.5. **The MANUAL Gas Generation Step**

The **MANUAL** step causes the T750 calibrator to enter **MANUAL CALIBRATION MODE**. It is programmed in a similar manner to the calibrator's **GENERATE → MANUAL** function. At the end of the programming sequence, the T750 firmware will automatically insert a DURATION step that needs to be defined.

To insert a **MANUAL** step into a sequence, press:

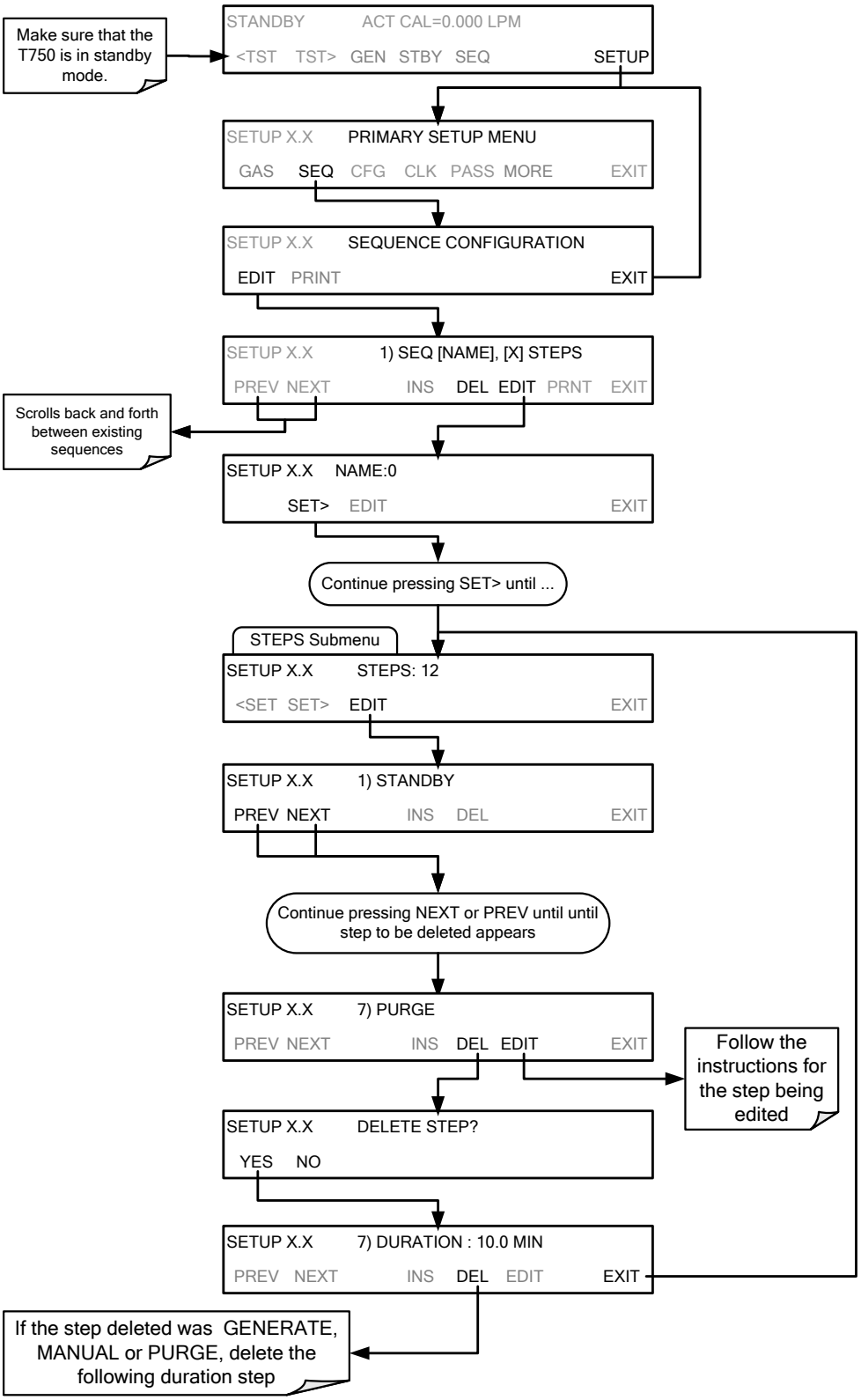


Note

If the user attempts to generate a source gas type that has not been entered into the T750's gas library, the sequence will freeze and after a certain time-out period, stop running.

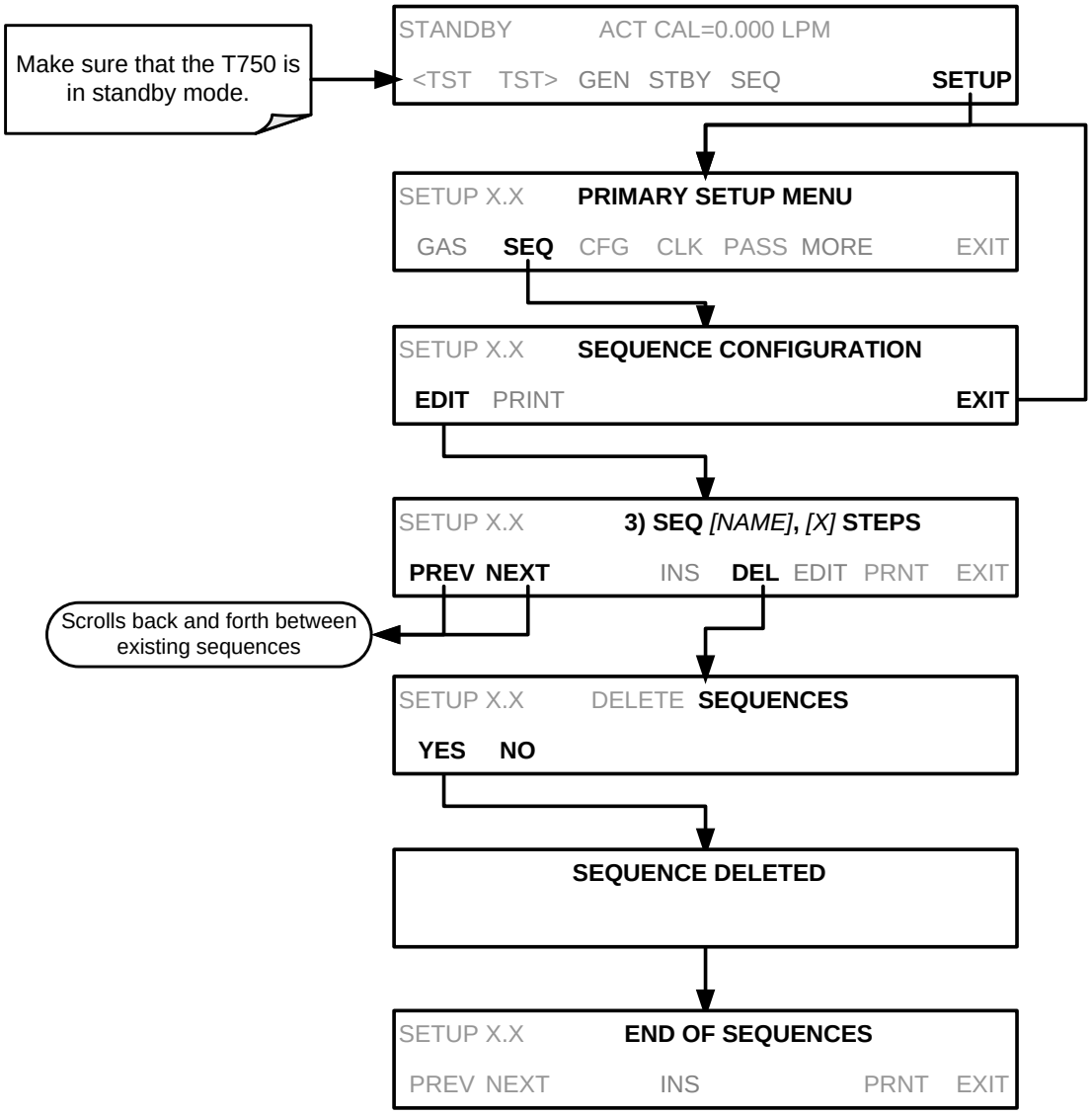
4.3.2.6. **Deleting or Editing an Individual Step in a Sequence**

To delete or edit an individual step in an existing Sequence, press:



4.3.3. **DELETING A SEQUENCE**

To delete a sequence from the T750 calibrator's memory, press:

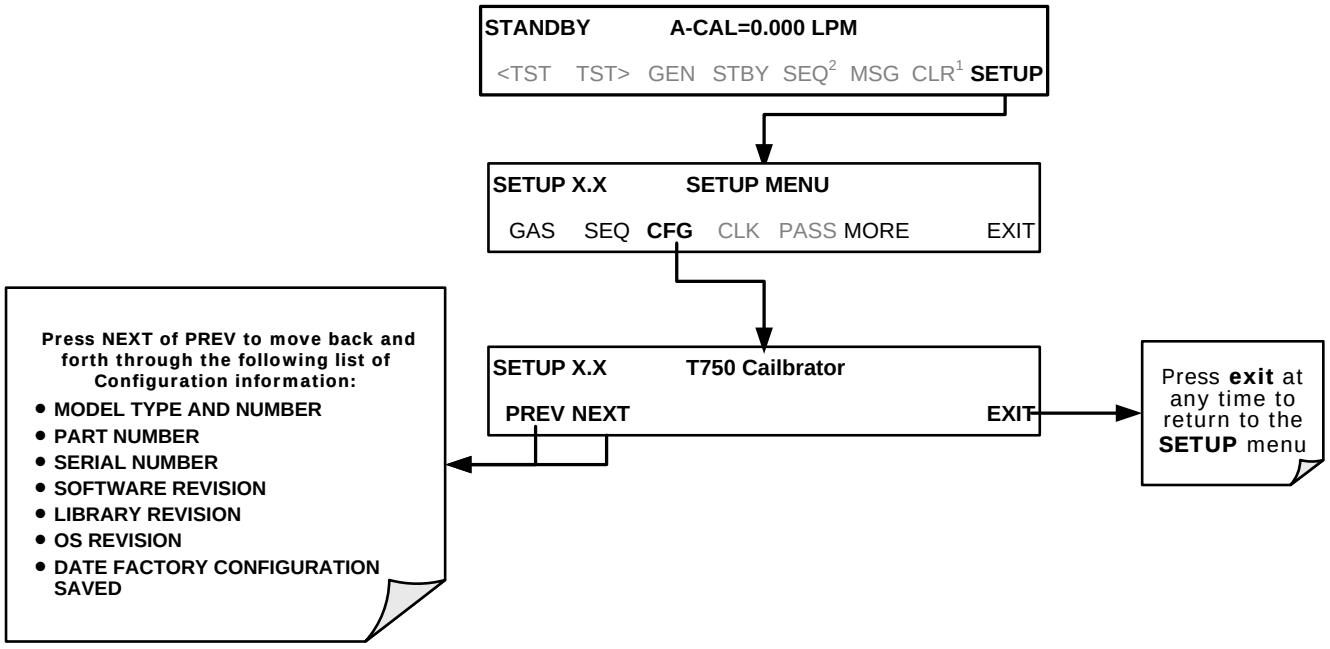


4.4. SETUP → CFG

Pressing the CFG button displays the instrument's configuration information. This display lists the calibrator 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.

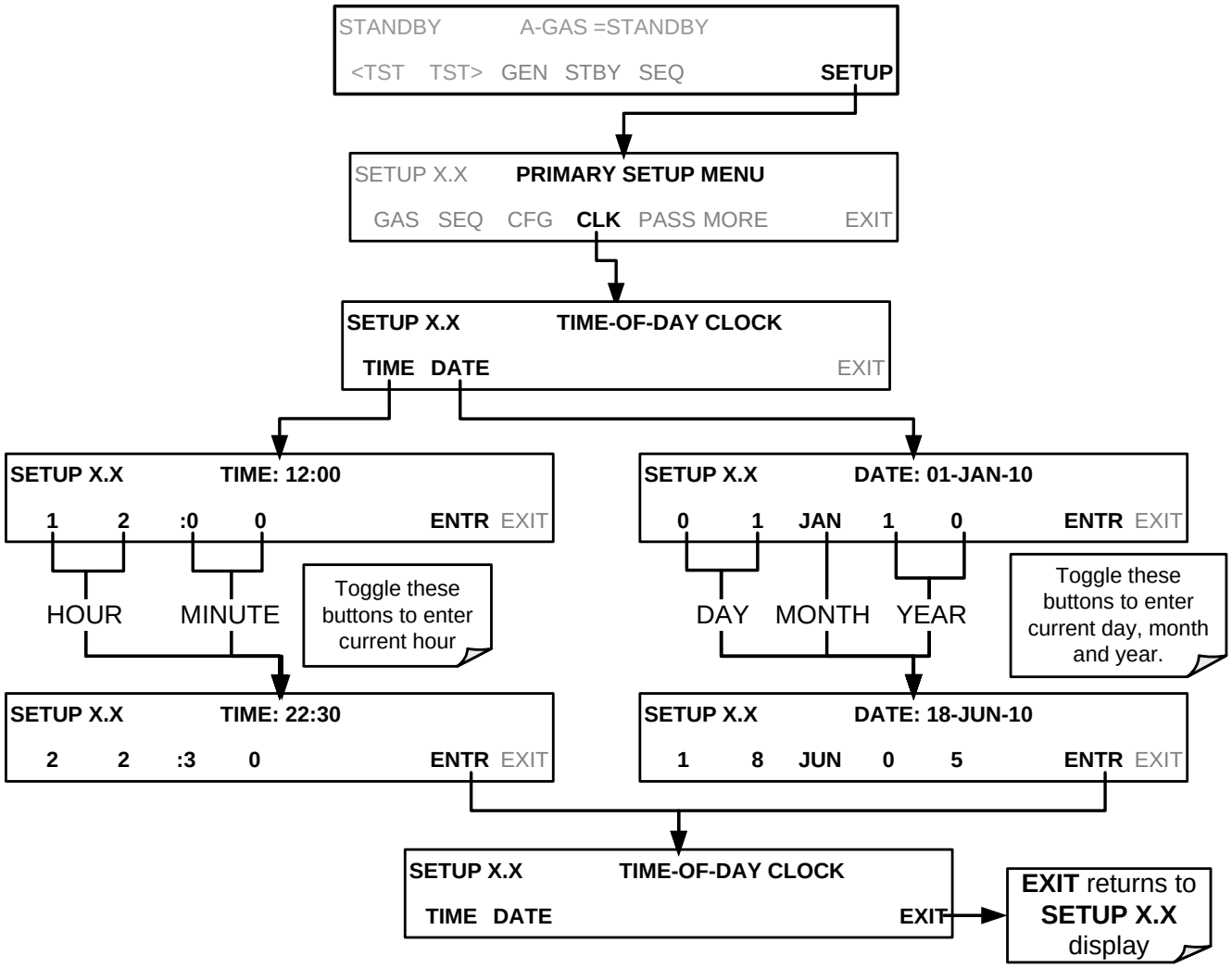
Special instrument or software features or installed options may also be listed here.



4.5. SETUP → CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK AND ADJUSTING SPEED

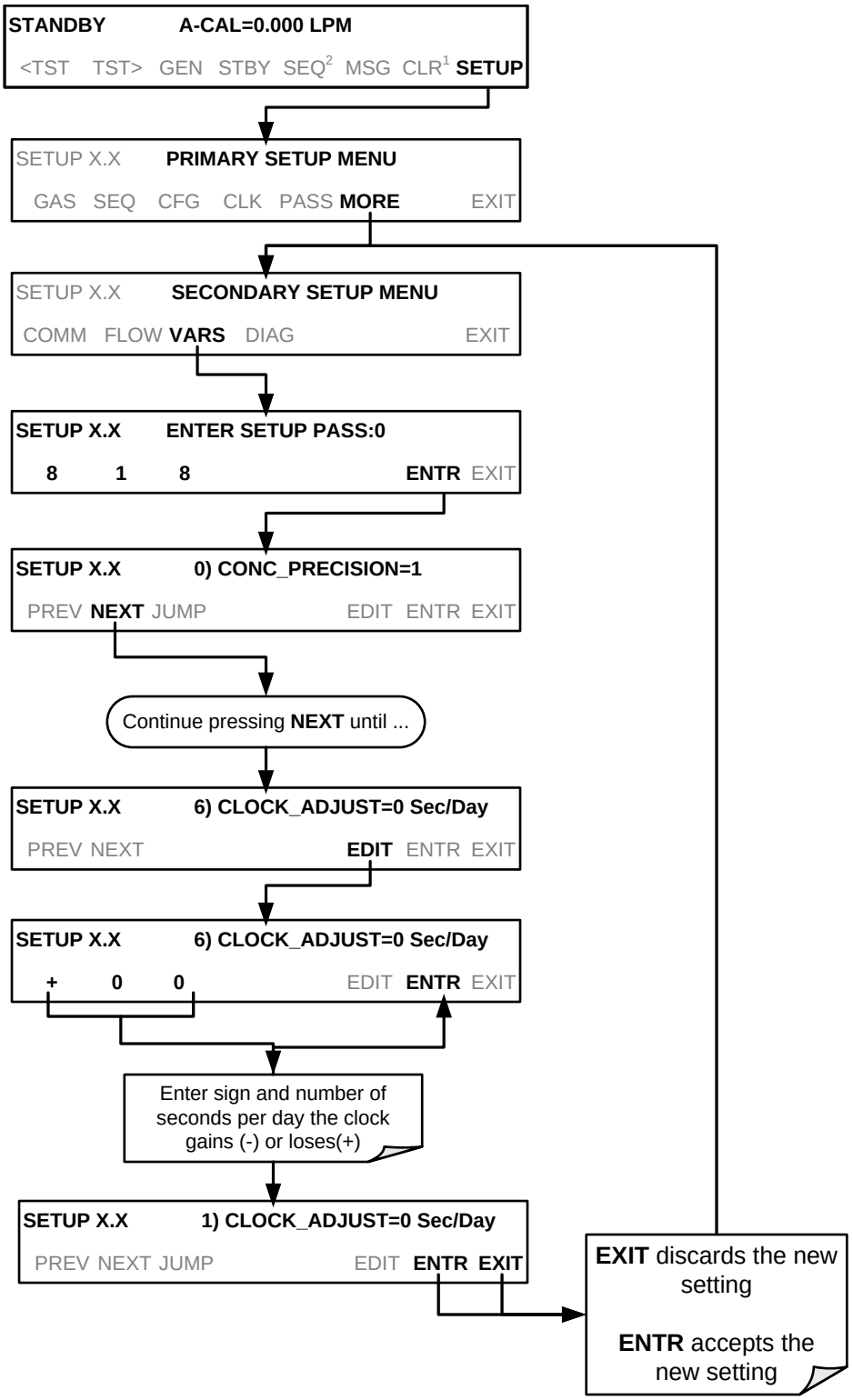
4.5.1. SETTING THE INTERNAL CLOCK'S TIME AND DAY

The T750 has a time of day clock that supports the **DURATION** step of the calibration sequence feature, time of day TEST function, and time stamps on most COMM port messages. To set the clock's time and day, press:



4.5.2. **ADJUSTING THE INTERNAL CLOCK'S SPEED**

In order to compensate for CPU clocks which run faster or slower, you can adjust a variable called **CLOCK_ADJ** to speed up or slow down the clock by a fixed amount every day. To change this variable, press:



4.6. SETUP → PASS

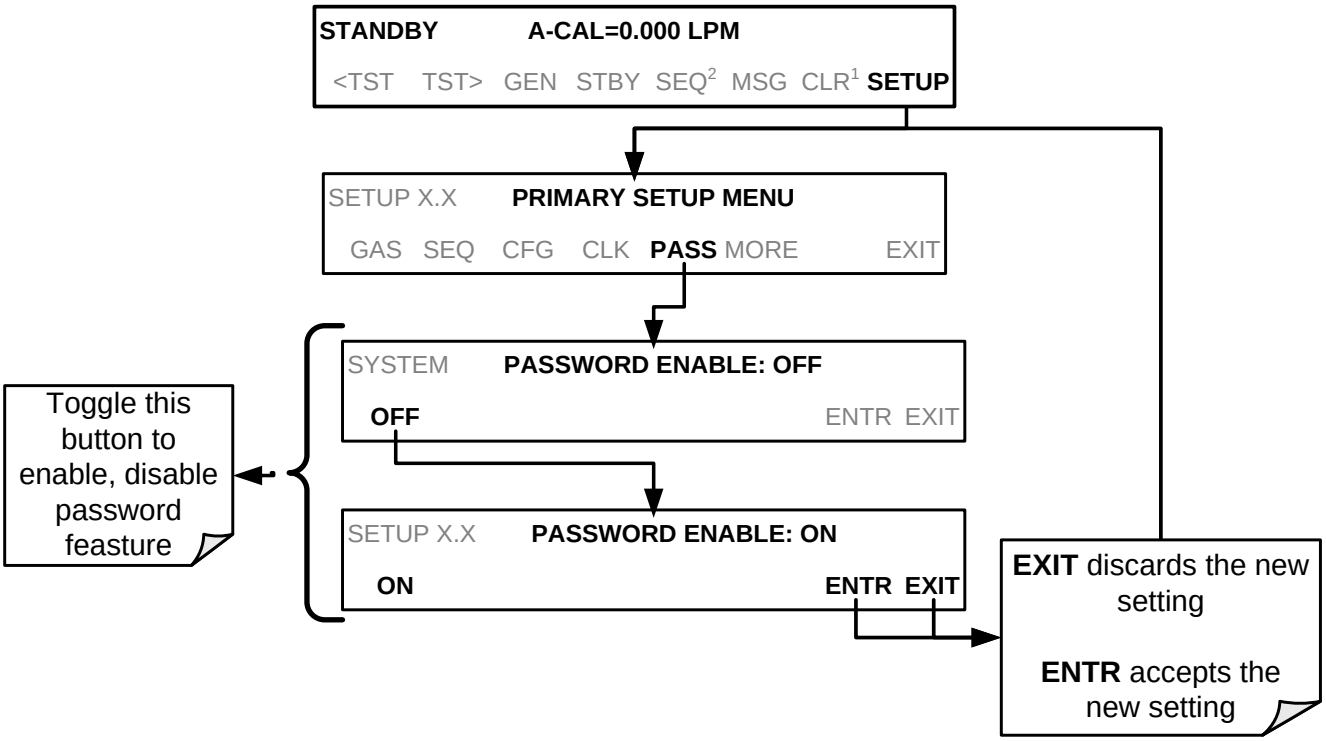
The T750 provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function is requested.

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.

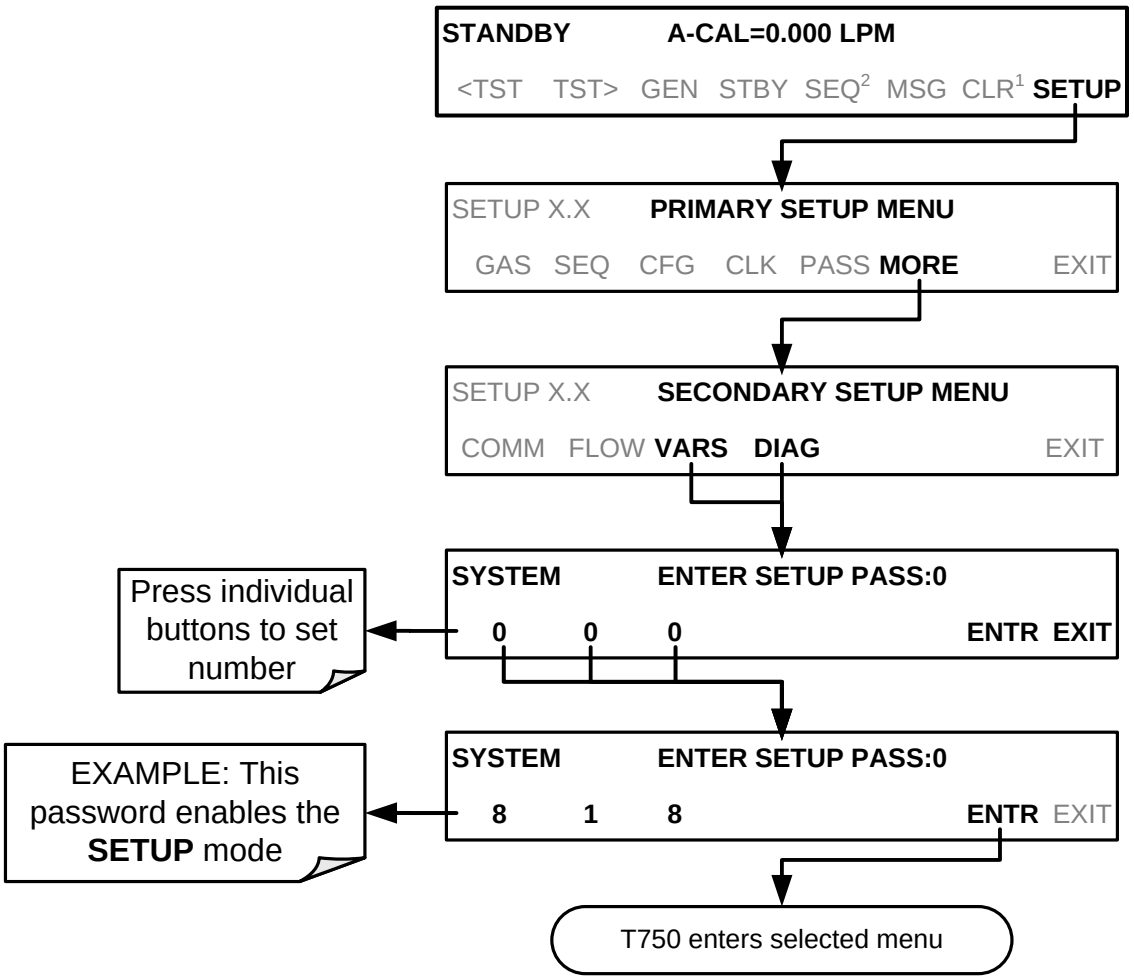
Table 4-11: Password Levels

PASSWORD	LEVEL	MENU ACCESS ALLOWED
No password	Operator	All functions of the MAIN menu: **TEST, GEN,** initiate **SEQ , MSG, CLR**
101	Maintenance	Access to Primary and Secondary Setup Menus except for **VARS** and **DIAG**
818	Configuration	Secondary SETUP Submenus **VARS** and **DIAG**

To enable or disable passwords, press:



Example: If all passwords are enabled, the following touch screen button sequence would be required to enter the VARS or DIAG submenus:



Note **The instrument still prompts for a password when entering the VARS and DIAG menus, even when passwords are disabled, but it displays the default password (818) upon entering these menus. Simply press ENTR when this is the case.**

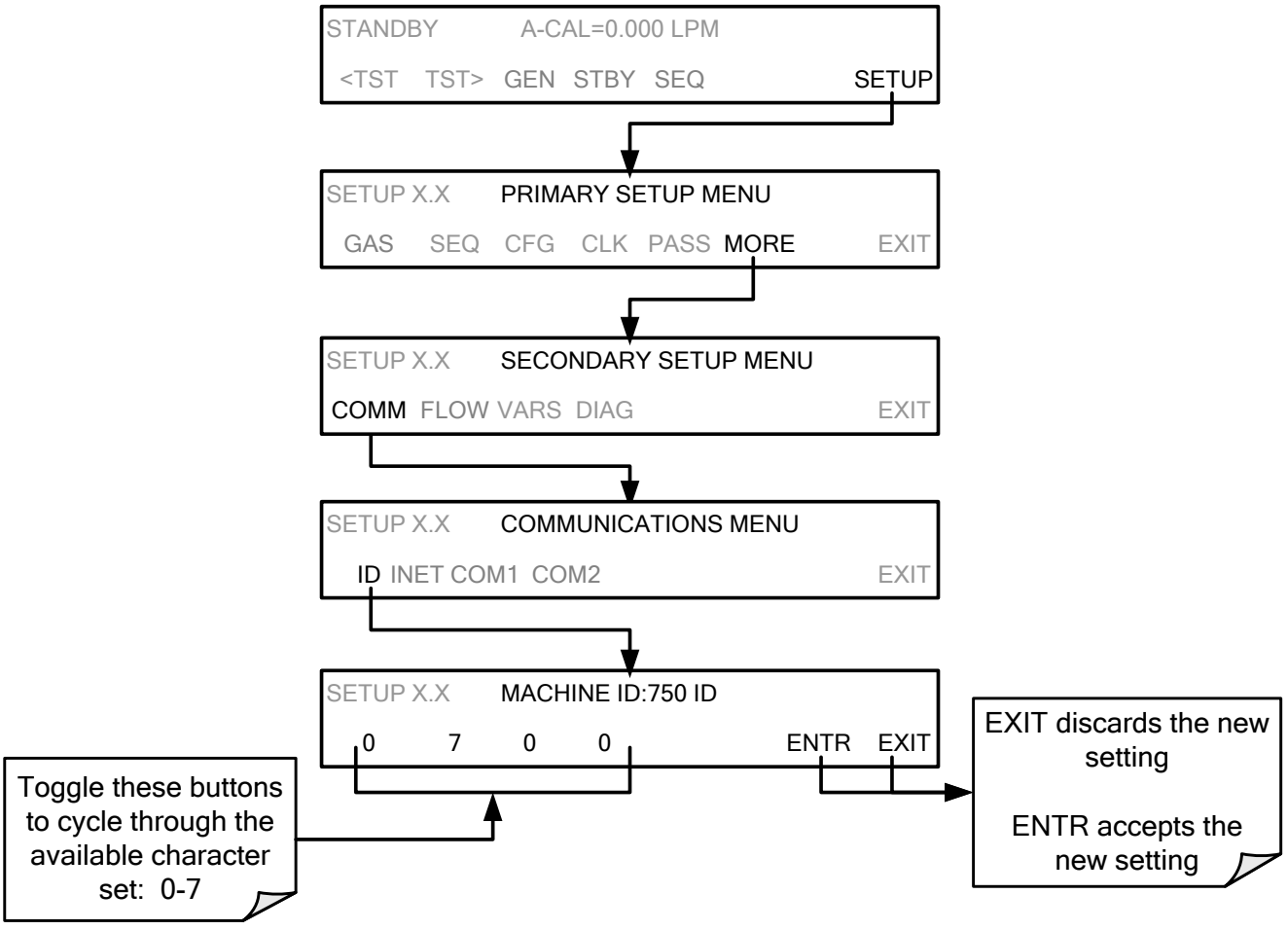
4.7. SETUP → COMM: COMMUNICATIONS PORTS

This section introduces the communications setup menu; Section 5 provides the setup instructions and operation information. Press SETUP>MORE>COMM to arrive at the communications menu.

4.7.1. ID (MACHINE IDENTIFICATION)

Each type of Teledyne API's calibrator is configured with a default ID code. The default ID code for all T750 calibrators is typically **750** (or **0**). The ID number is only important if more than one calibrator is connected to the same communications channel such as when several calibrators are on the same Ethernet LAN (see Section 5.4); in an RS-232 multi-drop chain (see Section3.4.1.6) or operating over a RS-485 network (see Section 5.3). If two calibrators of the same model type are used on one channel, the ID codes of one or both of the instruments need to be changed.

To edit the instrument's ID code, press:



The ID number is only important if more than one calibrator is connected to the same communications channel (e.g., a multi-drop setup). Different models of Teledyne API's calibrators have different default ID numbers, but if two calibrators of the same model type are used on one channel (for example, two T750's), the ID of one instrument needs to be changed.

The ID can also be used for to identify any one of several calibrators attached to the same network but situated in different physical locations.

4.7.2. INET (ETHERNET)

Use SETUP>COMM>INET to configure Ethernet communications, whether manually or via DHCP. Please see Section 5.4 for configuration details.

4.7.3. COM1 AND COM2 (MODE, BAUD RATE AND TEST PORT)

Use the SETUP>COMM>COM1[COM2] menus to:

- configure communication modes (Section 5.2.1)
- view/set the baud rate (Section 5.2.2)
- test the connections of the com ports (Section 5.2.3).

Configuring COM1 or COM2 requires setting the DCE DTE switch on the communications and output panel. Section 5.1 provides DCE DTE information.

4.8. SETUP → MORE → FLOW

The Flow menu allows you to view the performance statistics for the Mass Flow Controllers (MFCs). See Section 7.1 for more information and details on setting up for MFC flow verification and calibration.

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

The T750 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 redefined using the VARS menu.

The following table lists all variables that are available within the 818 password protected level. See Appendix A2 for a detailed listing of all of the T750 variables that are accessible through the remote interface.

Table 4-12: Variable Names (VARS)

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	DEFAULT VALUES
0	*PHOTO_LAMP [1,2]*	*Sets the photometer lamp temperature set point and warning limits.*	*0ºC and 100ºC*	*58ºC Warning limits 56ºC - 61ºC*
1	*O3_GEN LAMP [1,2]*	*Sets the O_3 generator lamp temperature set point and warning limits.*	*0ºC and 100ºC*	*48ºC Warning limits 43ºC - 53ºC*
2	**O3_CONC_RANGE**	Set the upper span point of the O_3 concentration range for TEST CHANNEL analog signal **O3_PHOTO_CONC**.	0.1–20000 ppb	500 ppb

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES	DEFAULT VALUES
3	**O3_PHOTO_BENCH_ONLY [2]**	O_3 bench control flag. • ON turns on the photometer pump and switches measure/reference valve only when the O_3 mode is set for BNCH (see Section 3.5.8).	ON/OFF	OFF
4	*STD_TEMP [1]*	*Sets the standard Temperature used in calculating O_3 flow rates and concentrations.*	*0ºC and 100ºC*	*25ºC*
5	*STD PRESSURE [1]*	*Sets the standard pressure used in calculating O_3 flow rates and concentrations.*	*15.00 – 50 .00 in-Hg-A*	*29.92 in-Hg-A*
6	**CLOCK_ADJ**	Adjusts the speed of the instrument's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast (see Section 4.5).	-60 to +60 s/day Default=0	0
7	**SERVICE_CLEAR**	ON resets the service interval timer	ON/OFF	OFF
8	**TIME_SINCE_SVC**	Time in hours since SERVICE_CLR turned ON	0 - 500000	0
9	**SVC_INTERVAL**	Sets the interval in hours between service reminders	0-100000	0

[1] **DO NOT ADJUST OR CHANGE** these values unless instructed to by Teledyne API's technical support personnel.

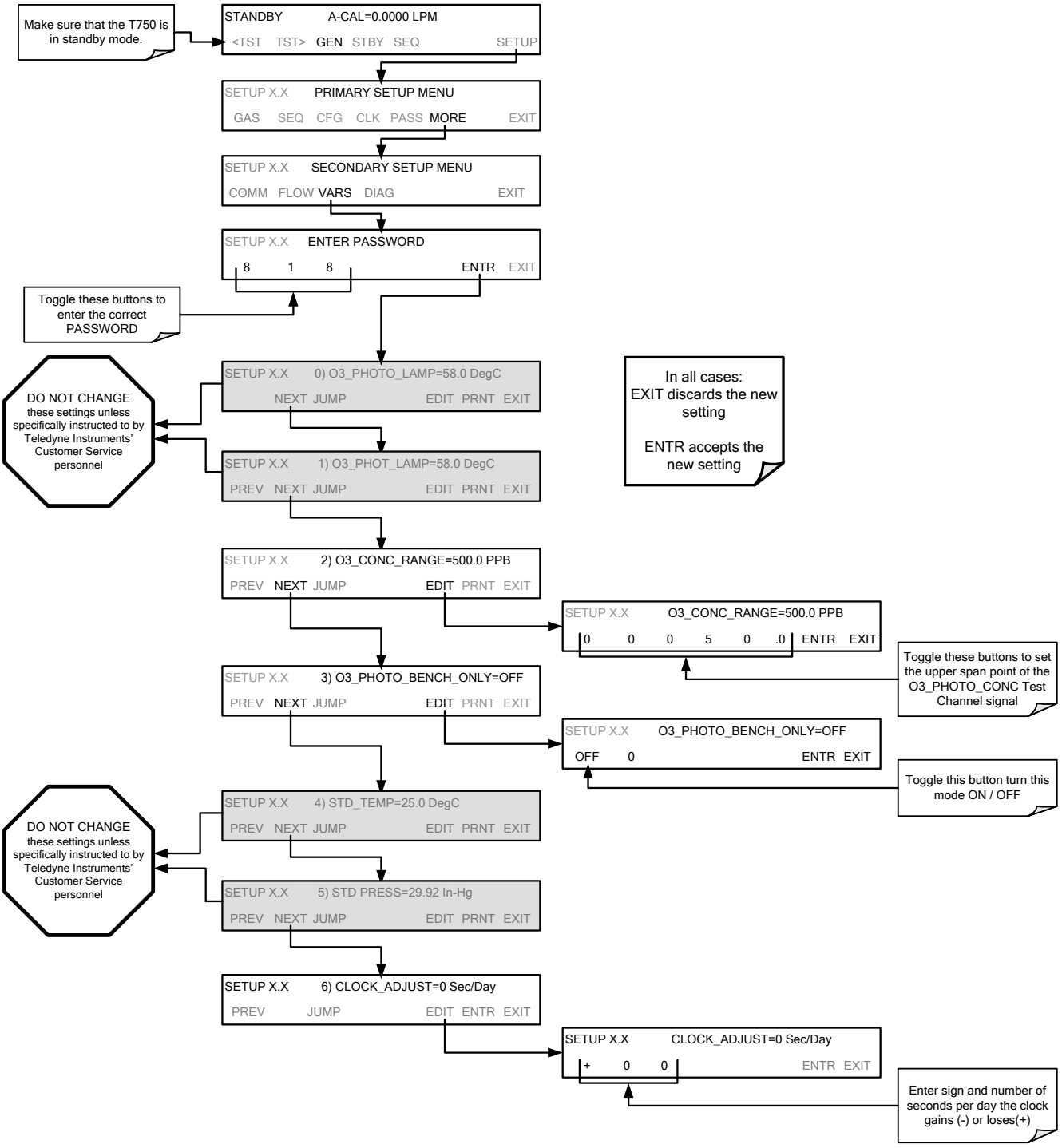
[2] Only available in calibrators with O_3 photometer and generator options installed.

IMPORTANT

IMPACT ON READINGS OR DATA

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

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



4.10. SETUP → MORE → DIAG: DIAGNOSTICS FUNCTIONS

A series of diagnostic tools is grouped together under the **SETUP→MORE→DIAG** menu, as these parameters are dependent on firmware revision (see Appendix A). These tools can be used in a variety of troubleshooting and diagnostic procedures and are referred to in many places of the maintenance and troubleshooting sections of this manual (see Sections 9.1 and 9.2).

This section shall focus on the test channel analog output.

4.10.1. → TEST CHAN OUTPUT: USING THE TEST CHANNEL ANALOG OUTPUT

The T750 calibrator comes equipped with one analog output. It can be set by the user to carry the current signal level of any one of the parameters listed in Table 4-14 and will output an analog VDC signal that rises and falls in relationship with the value of the parameter.

Pin-outs for the analog output connector at the communications and output panel of the instrument are:

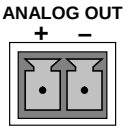


Figure 4-10: T750 the TEST CHANNEL Connector

4.10.1.1. Configuring the Test Channel Analog Output

Table 4-13 lists the analog I/O functions that are available in the T750 calibrator.

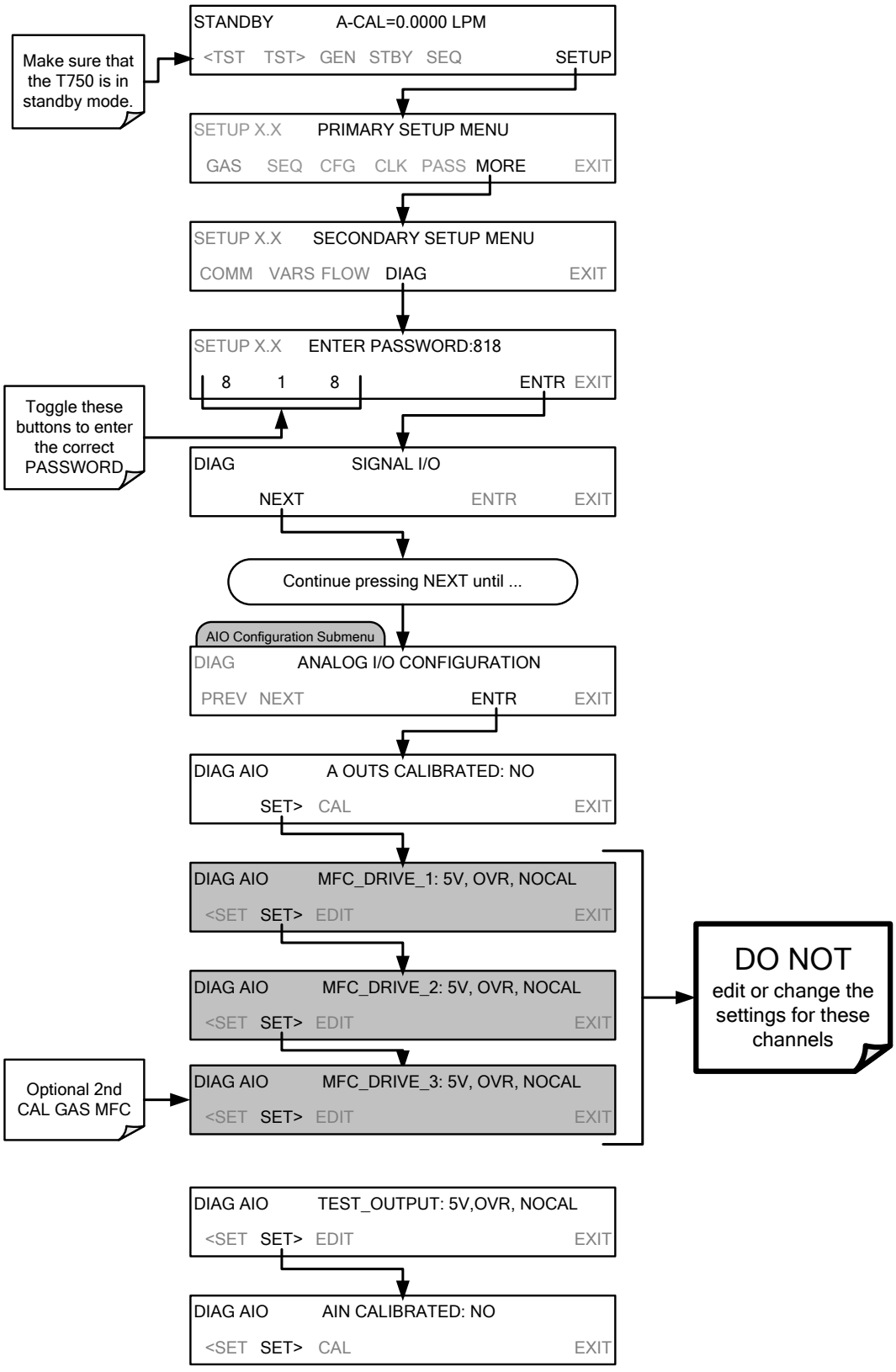
Table 4-13: DIAG – Analog I/O Functions

SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
MFC_DRIVE_1	**These channels are used by the T750 calibrator internally as drive voltages for instruments with analog MFCs.** **DO NOT alter the settings for these channels.**
MFC_DRIVE_2	
MFC_DRIVE_3 (OPTIONAL)	
TEST OUTPUT	Configures the 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 **CURR**ent 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.
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog to digital converter circuit on the motherboard.
[1]Changes to **RANGE** or **REC_OFS** require recalibration of this output.	

To configure the calibrator's **TEST CHANNEL**, set the electronic signal type of each channel and calibrate the outputs. This consists of:

- Choosing a Test Channel function to be output on the channel (Table 4-14).
- Selecting a signal level that matches the input requirements of the recording device attached to the channel (Section 4.10.1.3).
- Determining if the over-range feature is needed and turn it on or off accordingly (Section 4.10.1.4).
- Adding a bipolar recorder offset to the signal if required (Section 4.10.1.5).
- Calibrating the output channel. This can be done automatically or manually for each channel (Section 4.10.1.6).

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



4.10.1.2. **Selecting a Test Channel Function to Output**

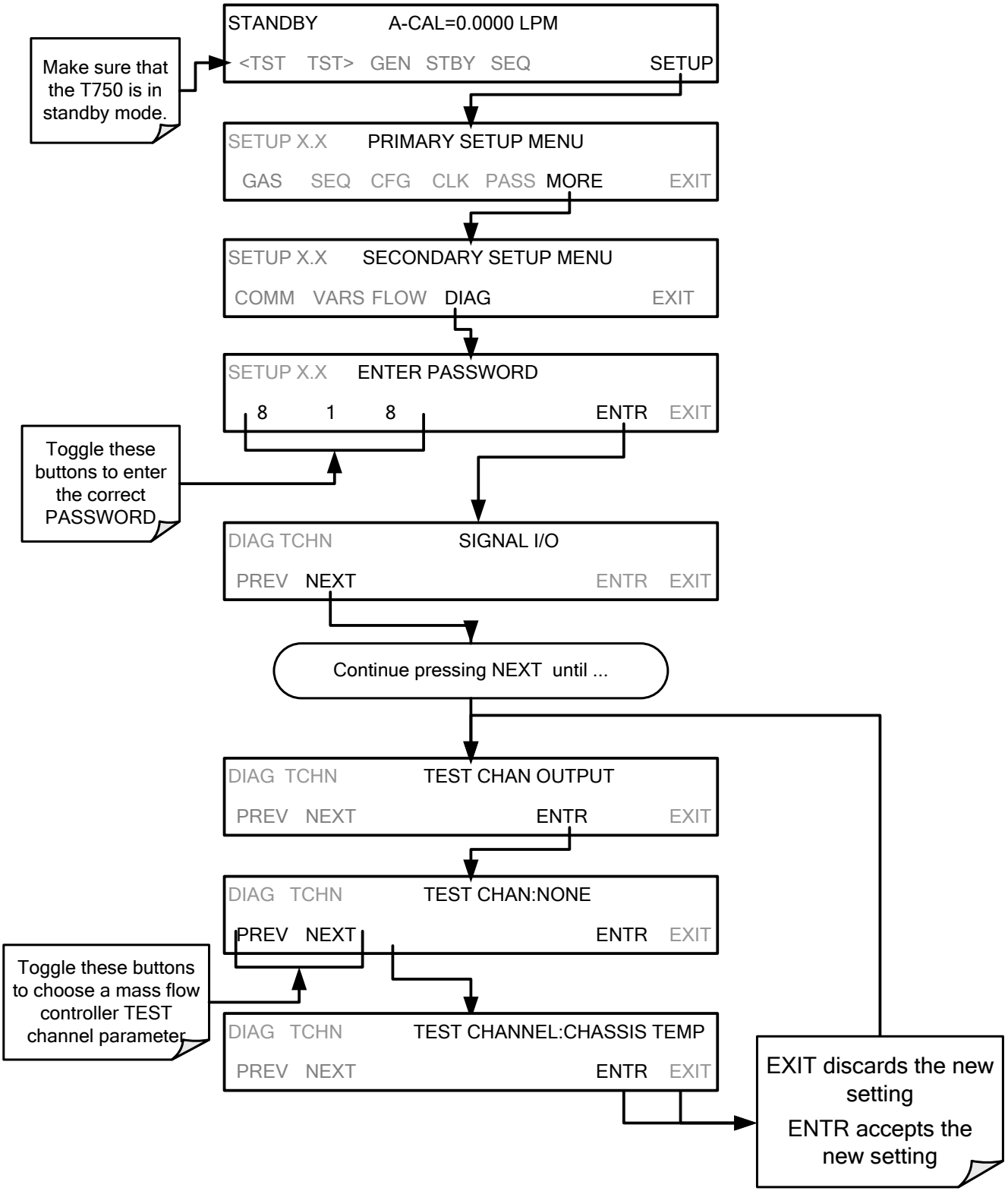
The Test Functions available to be reported are listed on Table 4-14:

Table 4-14: Test Channels Functions available on the T750's Analog Output

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE
NONE	**TEST CHANNEL IS TURNED OFF**		
O3 PHOTO MEAS	The raw output of the photometer during its measure cycle	0 mV	5000 mV
O3 PHOTO REF	The raw output of the photometer during its reference cycle	0 mV	5000 mV
REGULATOR PRESSURE	The gas pressure of the pressure regulator on the O_3 generator supply line	PSIG	PSIG
SAMPLE PRESSURE	The pressure of gas in the photometer absorption tube	0" Hg-In-A	40" Hg-In-A
SAMPLE FLOW	The gas flow rate through the photometer	0 cm^3/min	1000 cm^3/min
SAMPLE TEMP	The temperature of gas in the photometer absorption tube	0 C°	70 C°
PHOTO LAMP TEMP	The temperature of the photometer UV lamp	0 C°	70 C°
O3 LAMP TEMP	The temperature of the O_3 generator's UV lamp	0 mV	5000 mV
CHASSIS TEMP	The temperature inside the T750's chassis (same as **BOX TEMP**)	0 C°	70 C°
O3 PHOTO CONC	The current concentration of O_3 being measured by the photometer.	0 PPM	1 ppm

Once a function is selected, the instrument not only begins to output a signal on the analog output, but also adds **TEST** to the list of Test Functions viewable via the LCD touchscreen.

To activate the **TEST** Channel and select a function press:



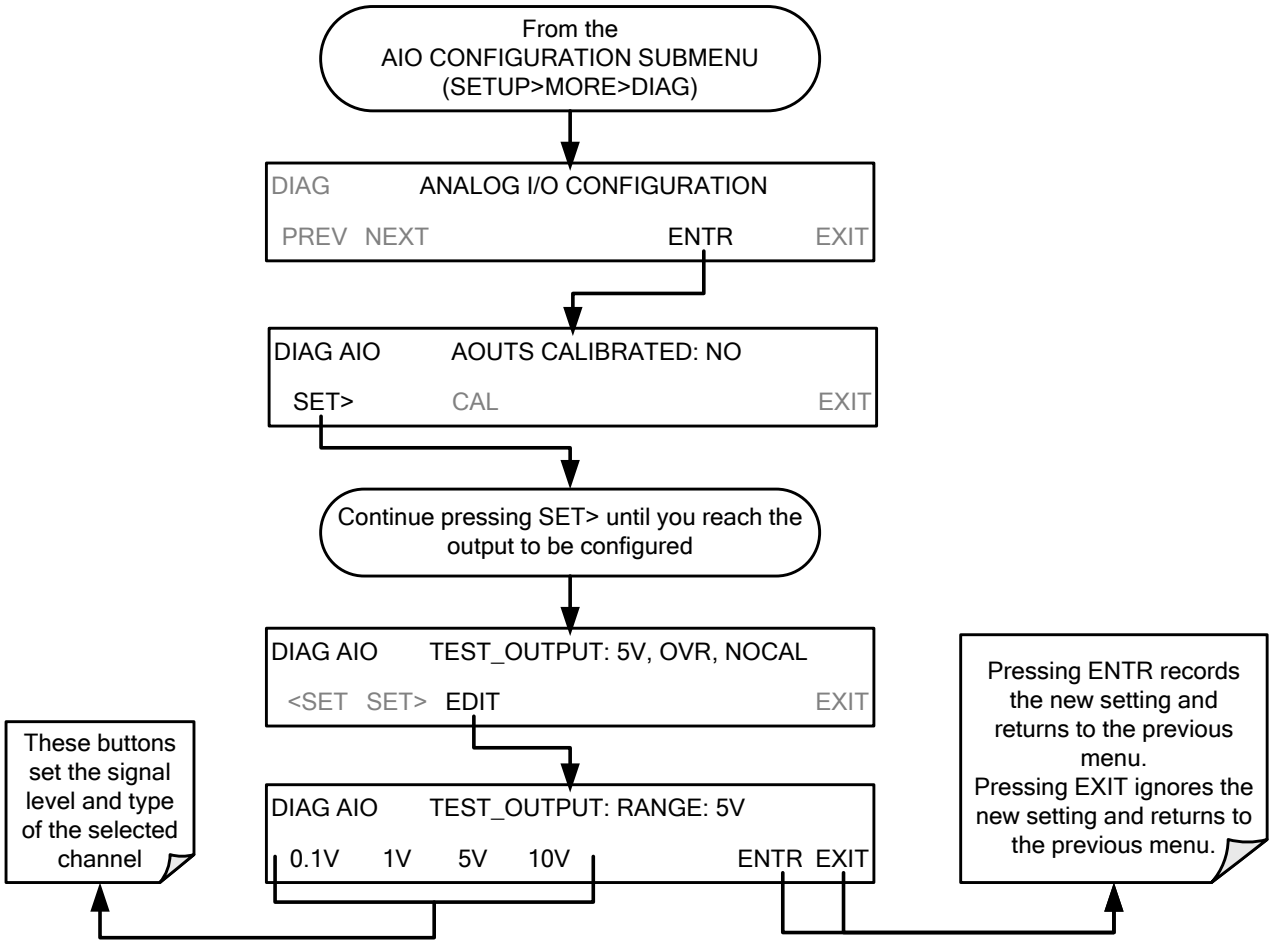
4.10.1.3. **Test Channel Voltage Range Configuration**

In its standard configuration, the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 4-15). Each range is usable from -5% to + 5% of the rated span.

Table 4-15: Analog Output Voltage Range Min/Max

RANGE SPAN	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-100 mVDC	-5 mVDC	105 mVDC
0-1 VDC	-0.05 VDC	1.05 VDC
0-5 VDC	-0.25 VDC	5.25 VDC
0-10 VDC	-0.5 VDC	10.5 VDC
The default offset for all ranges is 0 VDC.		

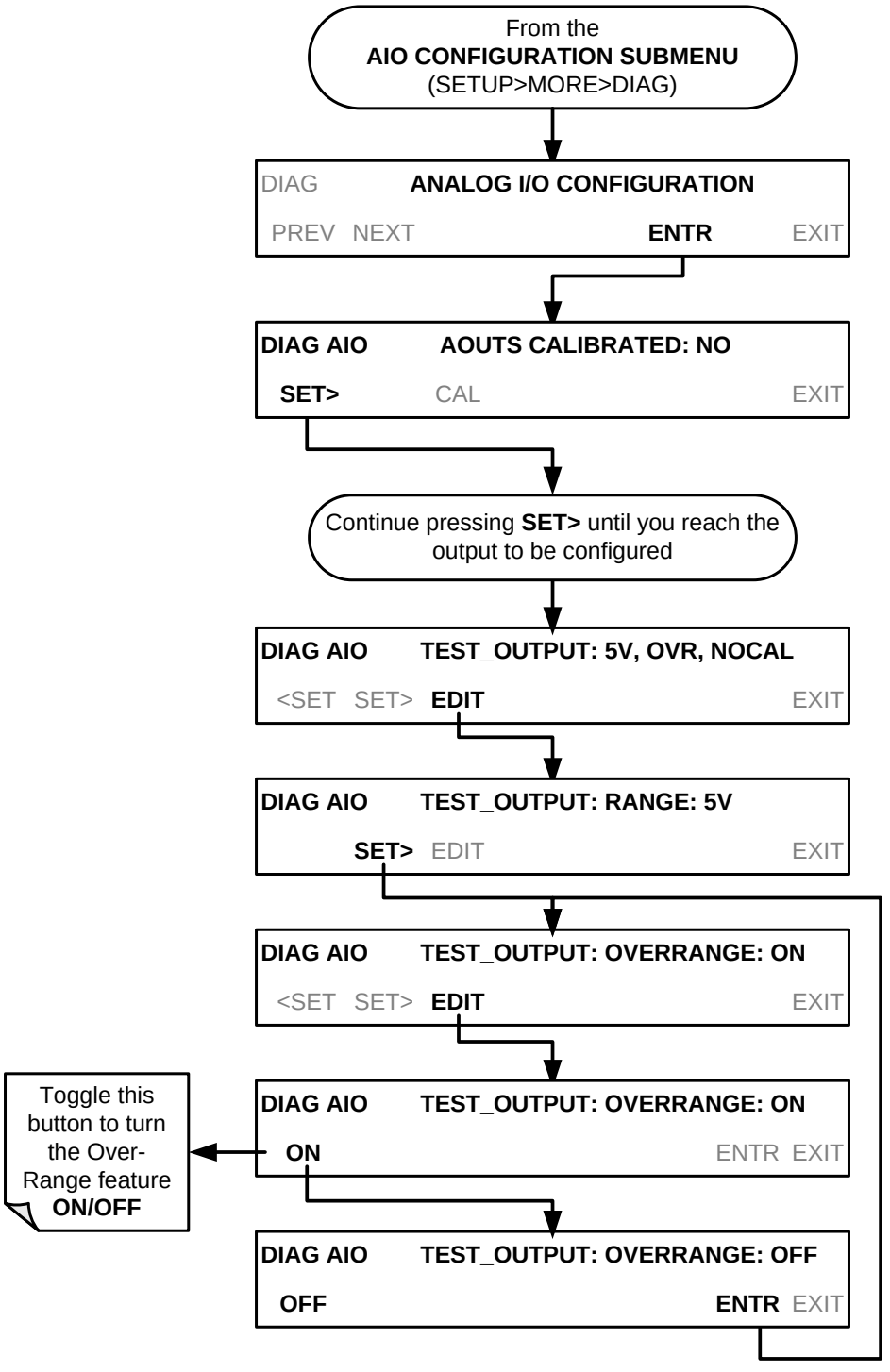
To change the output range, press:



4.10.1.4. **Turning the Test Channel Over-Range Feature ON/OFF**

In its default configuration, a ± 5% over-range is available on each of the T750's **TEST CHANNEL** output. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

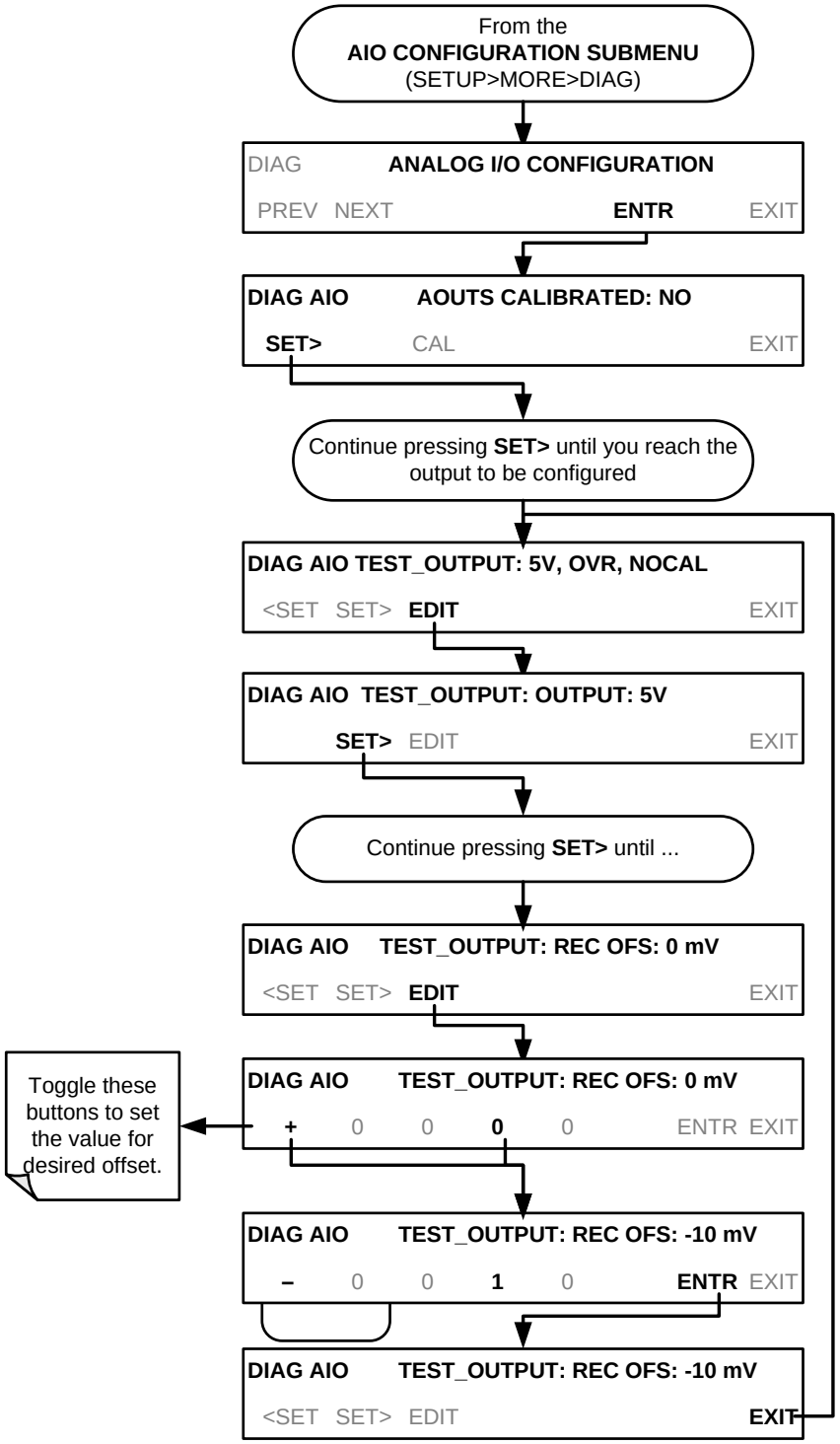
To turn the over-range feature on or off, press:



4.10.1.5. **Adding a Recorder Offset to the Test Channel**

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 T750 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:



4.10.1.6. **Test Channel Calibration**

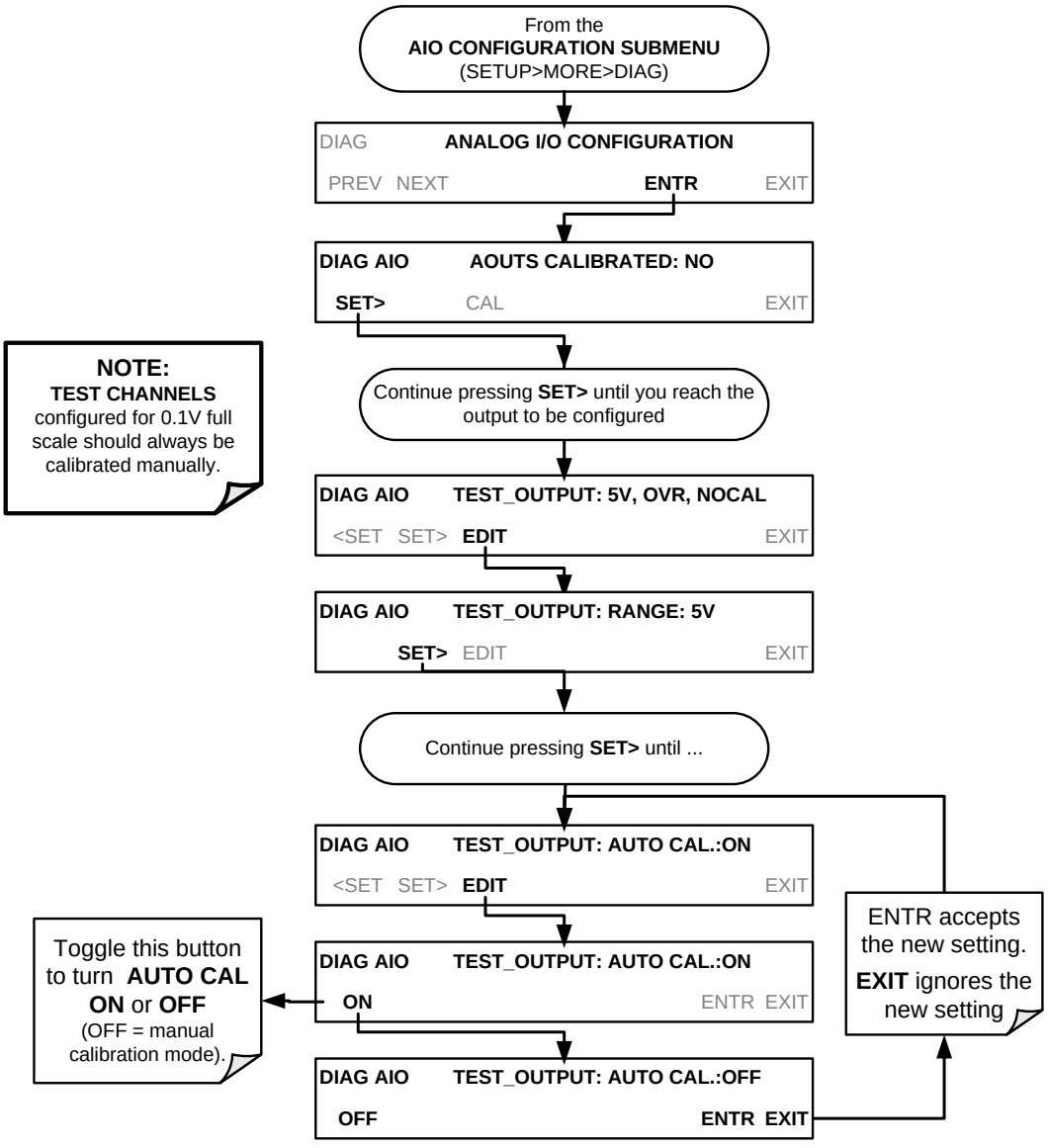
TEST CHANNEL calibration needs to be carried out on first startup of the calibrator (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically or adjusted manually.

In its default mode, the instrument is configured for automatic calibration of all channels, which is useful for clearing any analog calibration warnings associated with channels that will not be used or connected to any input or recording device, e.g., data logger.

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 AUTOCAL feature to be disabled.

ENABLING OR DISABLING THE TEST CHANNEL AUTOCAL FEATURE

To enable or disable the AUTOCAL feature for the **TEST CHANNEL**, press:

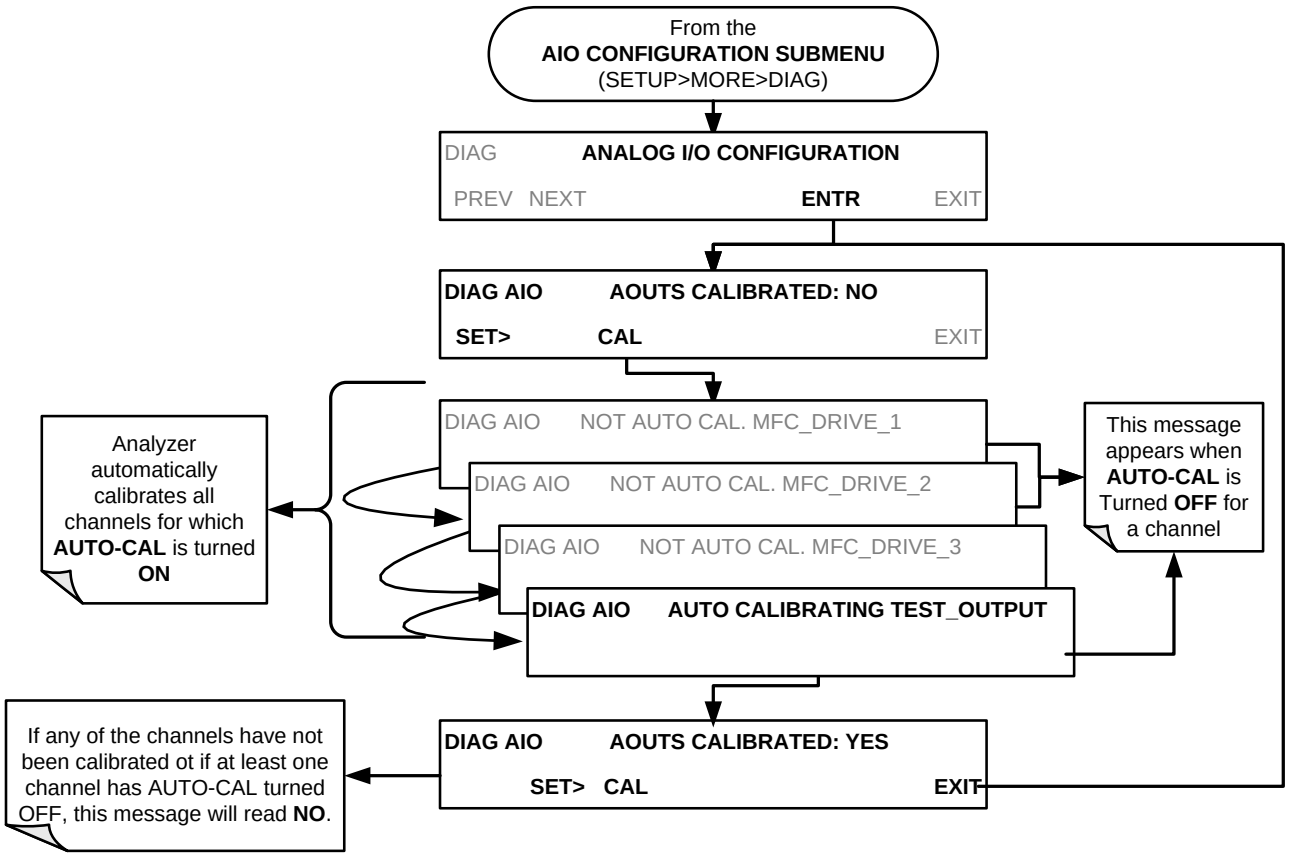


AUTOMATIC TEST CHANNEL CALIBRATION

Note

Before performing this procedure, ensure that the AUTO CAL feature is turned OFF for MFC_DRIVE_1, MFC_DRIVE_2 and MFC_DRIVE_3 if installed). Ensure that the AUTO CAL feature is turned ON for the TEST CHANNEL (see Section 4.10.1.6).

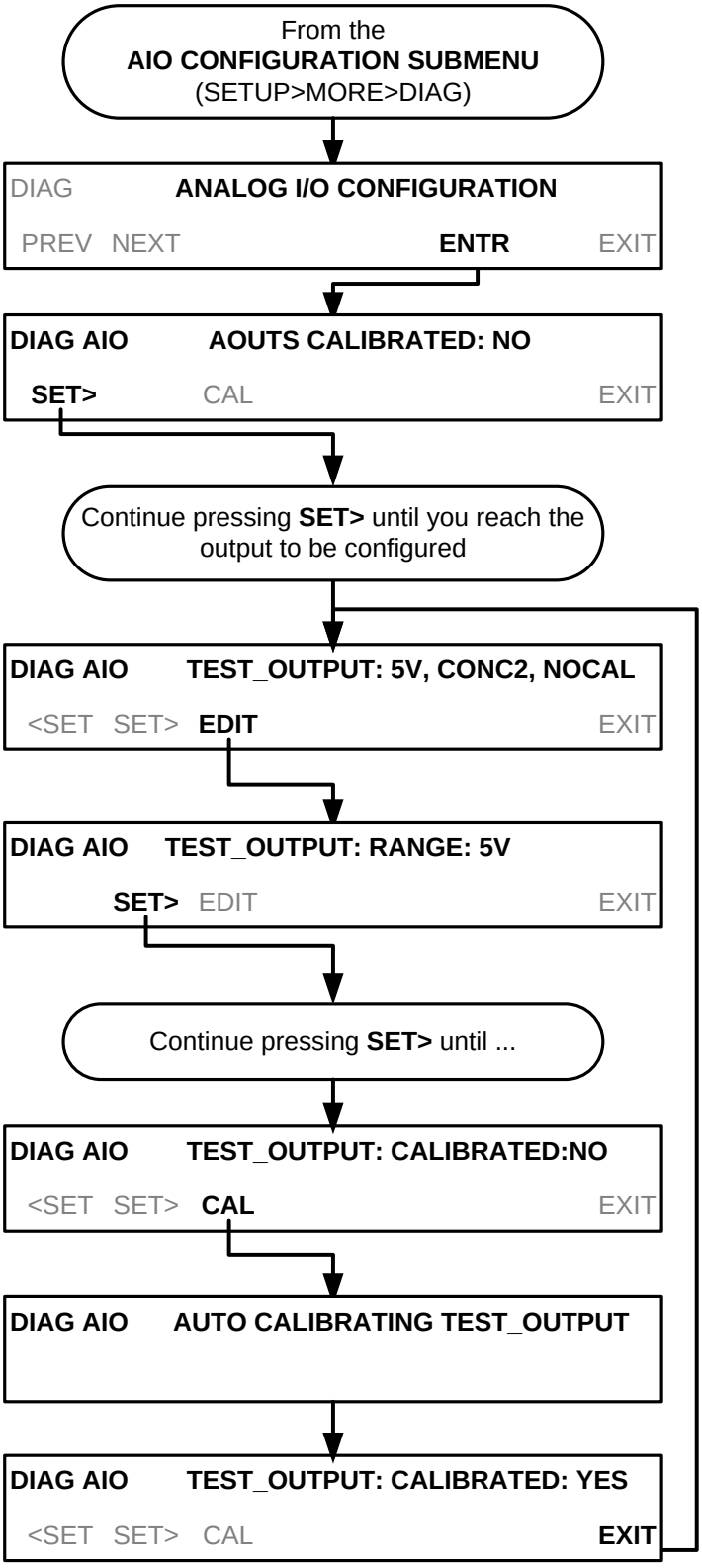
To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, press:



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. Manual calibration requires that the AUTOCAL feature be disabled.

To initiate an automatic calibration from inside the **TEST CHANNEL** submenu, press:



MANUAL CALIBRATION OF THE TEST CHANNEL CONFIGURED FOR VOLTAGE RANGES

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

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 (see Section 4.10.1.6).**

Calibration is performed with a voltmeter connected across the output terminals and by changing the actual output signal level using the LCD touchscreen buttons in 100, 10 or 1 count increments.

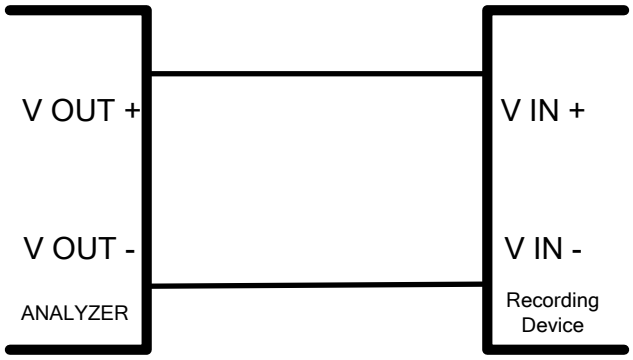
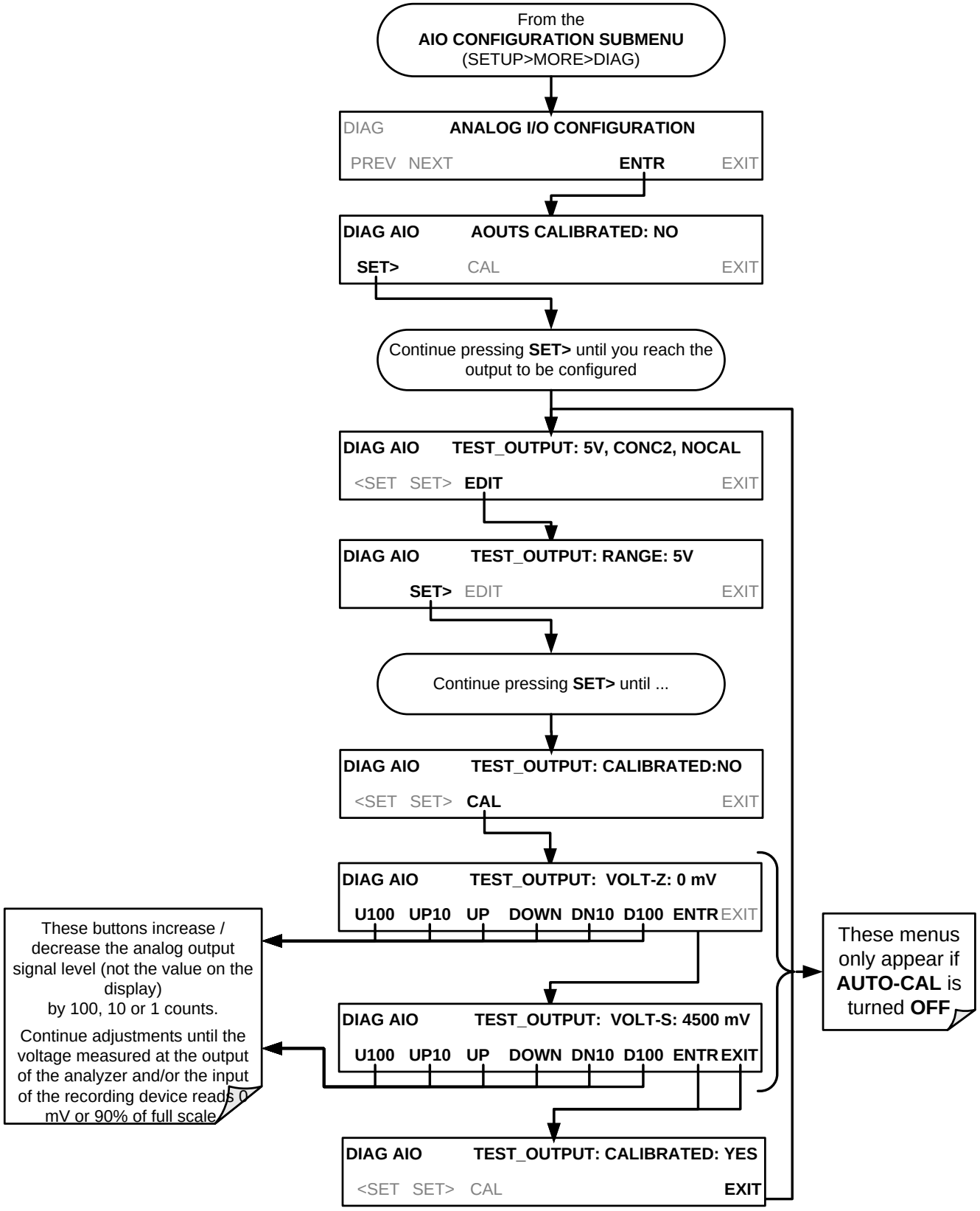


Figure 4-11: Setup for Calibrating the TEST CHANNEL

Table 4-16: Voltage Tolerances for the TEST CHANNEL 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

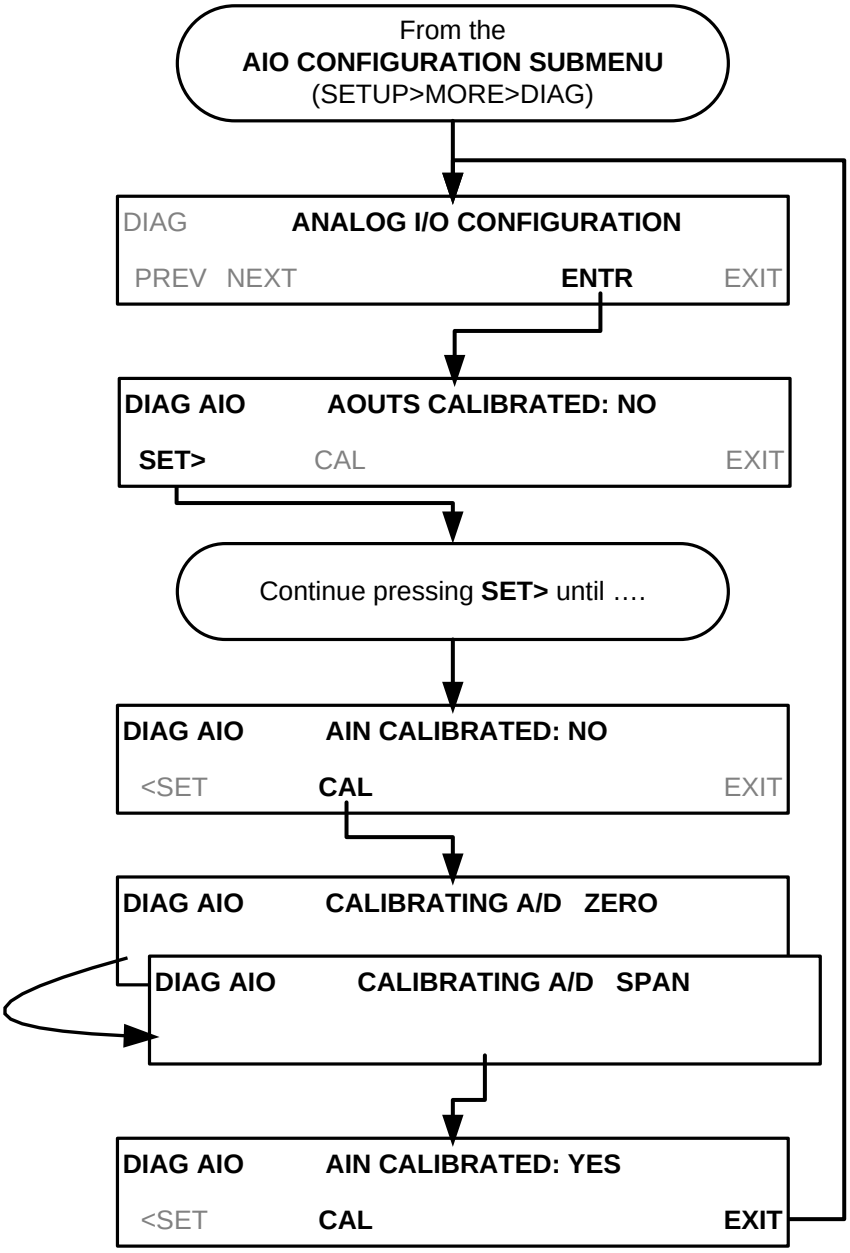
To adjust the signal levels of an analog output channel manually, press:



4.10.1.7. **AIN Calibration**

This is the sub-menu in which to calibrate the A-to-D conversion circuitry (Sections 9.4.10.1 and 10.3.4.1). This calibration is only necessary after a major repair such as the replacement of a CPU, a motherboard or a power supply.

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



5. COMMUNICATIONS SETUP AND OPERATION

The instrument communications and output panel connections include an Ethernet port, a USB port (option) and two serial communications ports (labeled RS232, which is the COM1 port, and COM2) located on the communications and output panel (refer to Figure 3-5). These ports give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal.

This section provides pertinent information regarding communication equipment, describes the instrument's communications modes, presents configuration instructions for the communications ports, and provides instructions for their use.

5.1. DATA TERMINAL/COMMUNICATION EQUIPMENT (DTE DCE)

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 communications and output panel allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

The T750 is equipped with two serial communication ports (labeled **RS232** and **COM2**), a USB com port and an Ethernet port located on the communications and output panel. The two serial ports are accessible via two DB-9 connectors (see Figure 3-5): RS232 (COM1), a male DB-9 connector, and COM2, a female DB9 connector.

The RS232 and COM2 ports operate similarly and give the user the ability to communicate with, issue commands to, and receive data from the calibrator through an external computer system or terminal.

- The RS-232 port (COM1) can also be configured to operate in single or RS-232 multi-drop mode (option 62, Sections 3.4.1.6 and 5.2).
- The COM2 port can be configured for standard RS-232 operation, half-duplex RS-485 communication. (Contact the factory for RS-485 communication configuration).

The Ethernet connector allows the analyzer to be connected to a network running TCP/IP or to the public Internet if access is available. The network must have routers

capable of operating at 10BaseT or 100BaseT. DHCP is enabled by default (Section 5.4.1). 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 5.4.1.1). Edit the Instrument and Gateway IP addresses and Subnet Mask to the desired settings. Then, from the computer, enter the same information through an application such as HyperTerminal.

The USB port is for optional direct communication between the calibrator and a desktop or laptop computer. This configuration can be used when the **COM2** port is not in use except for multidrop communication. For setup instructions, please refer to Sections 3.4.1.6 and 5.2.1.

5.2. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

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

5.2.1. COMMUNICATION MODES

Each of the calibrator's serial ports can be configured to operate in a number of different modes, listed in Table 5-1. As modes are selected, the calibrator sums the Mode ID numbers and displays this combined number on the LCD touchscreen. For example, if quiet mode (01), computer mode (02) and Multi-Drop-enabled mode (32) are selected, the Calibrator would display a combined **MODE ID** of **35**.

Table 5-1: COMM Port Communication Modes

MODE[1]	ID	DESCRIPTION
QUIET	**1**	Quiet mode suppresses any feedback from the calibrator (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. 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 operated control program.
E,8,1 / E,7,1	**2048**	When turned on this mode switches the **COMM** port settings from No parity; 8 data bits; 1 stop bit to Even parity; 7 data bits; 1 stop bit
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).
RS-485	**1024**	Configures the **COM2** Port for RS-485 communication. RS-485 mode has precedence over multi-drop mode if both are enabled.
MULTI-DROP PROTOCOL	**32**	Multi-drop protocol allows a multi-instrument configuration on a single communications channel. Multi-drop requires the use of instrument IDs.
ENABLE MODEM	**64**	Enables to send 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.

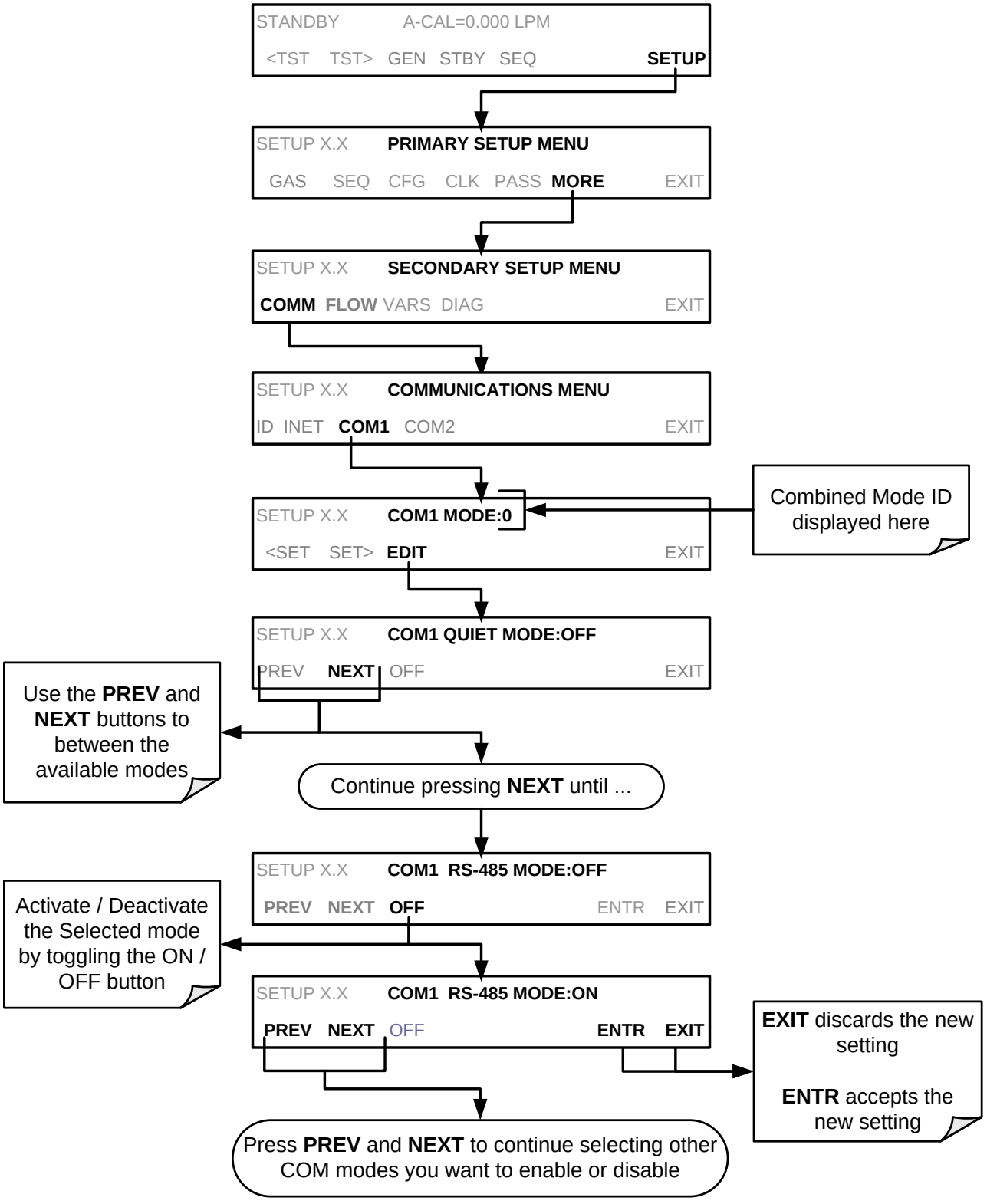
MODE[1]	ID	DESCRIPTION
XON/XOFF HANDSHAKE[2]	**256**	Disables XON/XOFF data flow control also known as software handshaking.
HARDWARE HANDSHAKE	**8**	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO[2]	**512**	Disables the **HARDWARE FIFO** (First In – First Out), When FIFO is enabled it improves data transfer rate for that COMM port.
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 → COMM → COM[1 OR 2] → MODE** menu

[2] The default setting for this feature is **ON.** Do not disable unless instructed to by Teledyne API's Technical Support personnel.

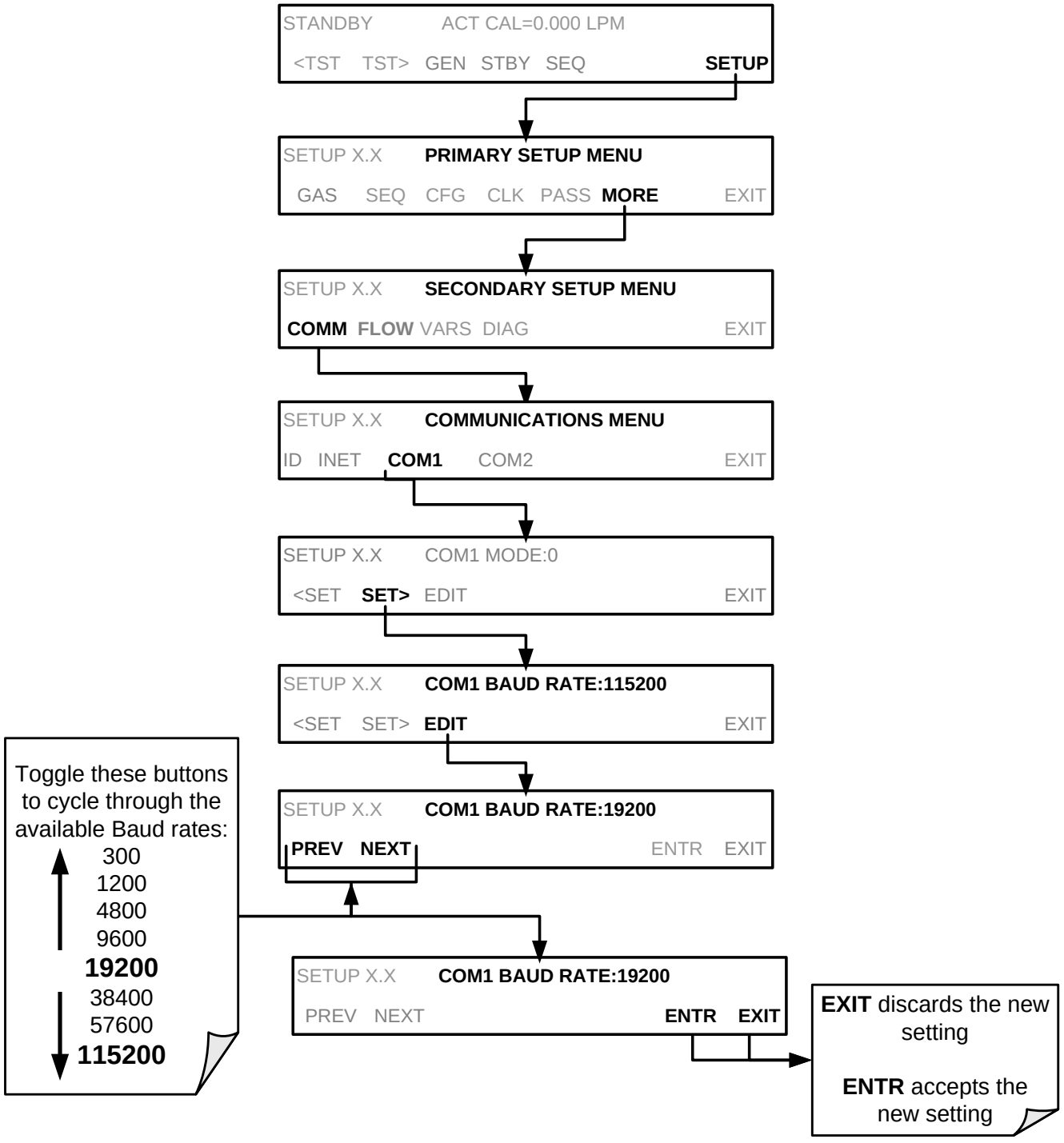
Note **Communication Modes for each COMM port must be configured independently.**

Press the following buttons to select communication modes for a one of the COMM Ports, such as the following example where **RS-485** mode is enabled:


STANDBY A-CAL=0.000 LPM
<TST TST> GEN STBY SEQ SETUP
SETUP X.X PRIMARY SETUP MENU
GAS SEQ CFG CLK PASS MORE EXIT
SETUP X.X SECONDARY SETUP MENU
COMM FLOW VARS DIAG EXIT
SETUP X.X COMMUNICATIONS MENU
ID INET COM1 COM2 EXIT
SETUP X.X COM1 MODE:0
<SET SET> EDIT EXIT
Combined Mode ID displayed here
SETUP X.X COM1 QUIET MODE:OFF
PREV NEXT OFF EXIT
Use the PREV and NEXT buttons to between the available modes
Continue pressing NEXT until ...
SETUP X.X COM1 RS-485 MODE:OFF
PREV NEXT OFF ENTR EXIT
Activate / Deactivate the Selected mode by toggling the ON / OFF button
SETUP X.X COM1 RS-485 MODE:ON
PREV NEXT OFF ENTR EXIT
EXIT discards the new setting
ENTR accepts the new setting
Press PREV and NEXT to continue selecting other COM modes you want to enable or disable

5.2.2. **COM PORT BAUD RATE**

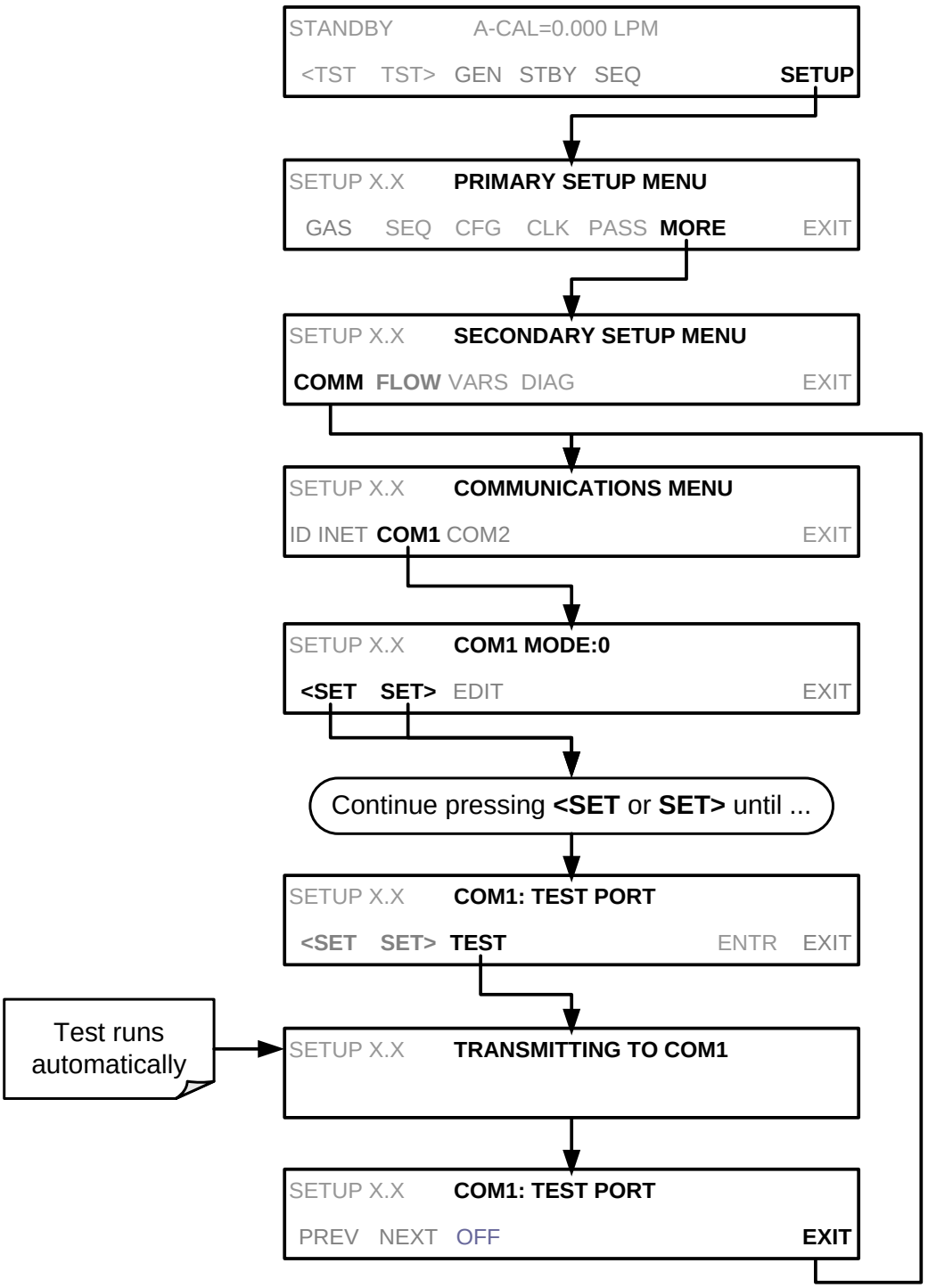
To select the baud rate of either COM Port, go to SETUP>MORE>COMM and select either COM1 or COM2 as follows (use COM2 to view/match your personal computer baud rate when using the USB port:



5.2.3. **COM PORT TESTING**

The serial ports can be tested for correct connection and output in the **COMM** 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 communications and output panel of the calibrator should flicker.

To initiate the test, press the following button sequence:



5.3. RS-485 (OPTION)

The COM2 port of the instrument's communications and output panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Technical Support. If this option was elected at the time of purchase, the communications and output panel was preconfigured at the factory. Choosing this option disallows use of the USB port.

5.4. REMOTE ACCESS VIA THE ETHERNET

Via the Ethernet interface, the calibrator 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 Internet to the calibrator using APICOM, terminal emulators or other programs.

Under the SETUP>MORE>COMM menu the **INET** submenu is used to manage and configure the Ethernet interface with your LAN or Internet Server(s). The calibrator is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server (Section 5.4.1), but for a permanent Ethernet connection, configure the instrument with a static IP address (Section 5.4.1.1).

The Ethernet LEDs located on the connector indicate the Ethernet connection status.

Table 5-2: Ethernet Status Indicators

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

5.4.1. CONFIGURING THE ETHERNET INTERFACE USING DHCP

The Ethernet feature for your T750 uses Dynamic Host Configuration Protocol (DHCP) to configure its interface with your LAN automatically. This requires your network servers also be running DHCP. The calibrator will do this the first time you turn the instrument on after it has been physically connected to your network. Once the instrument is connected and turned on, it will appear as an active device on your network without any extra set up steps or lengthy procedures.

Note **Check the INET settings the first time you power up your calibrator after it has been physically connected to the LAN/Internet to ensure that the DHCP has successfully downloaded the appropriate information from your network server(s).**

Table 5-3: LAN/Internet Configuration Properties

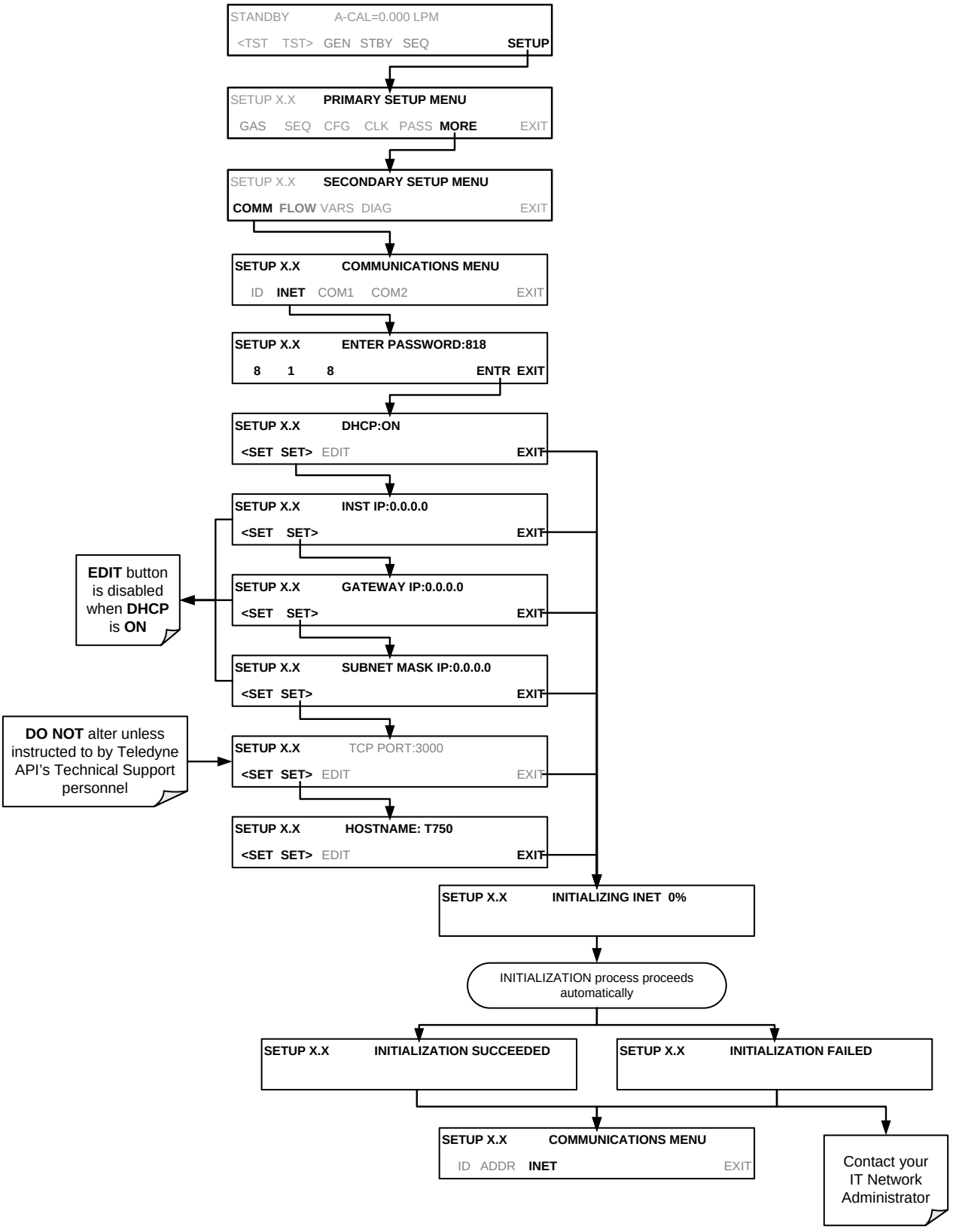
PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP STATUS	On	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	0.0.0.0	This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the calibrator itself.
GATEWAY IP ADDRESS	0.0.0.0	A string of numbers very similar 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	0.0.0.0	Also, a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent devices with different subnet masks are assumed to be outside of the LAN and are routed through a different gateway computer onto the Internet.
TCP PORT[1]	**3000**	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
HOST NAME	**T750**	The name by which your calibrator will appear when addressed from other computers on the LAN or via the Internet. While the default setting for all Teledyne API's T750 calibrators is "T750", the host name may be changed to fit customer needs.

[1] Do not change the setting for this property unless instructed to by Teledyne API's Technical Support personnel.

Note

If the gateway IP, instrument IP and the subnet mask are all zeroes (e.g. "0.0.0.0"), the DCHP was not successful in which case you may have to configure the calibrator's Ethernet properties manually. See your network administrator.

To view the above properties listed in Table 5-3, press:

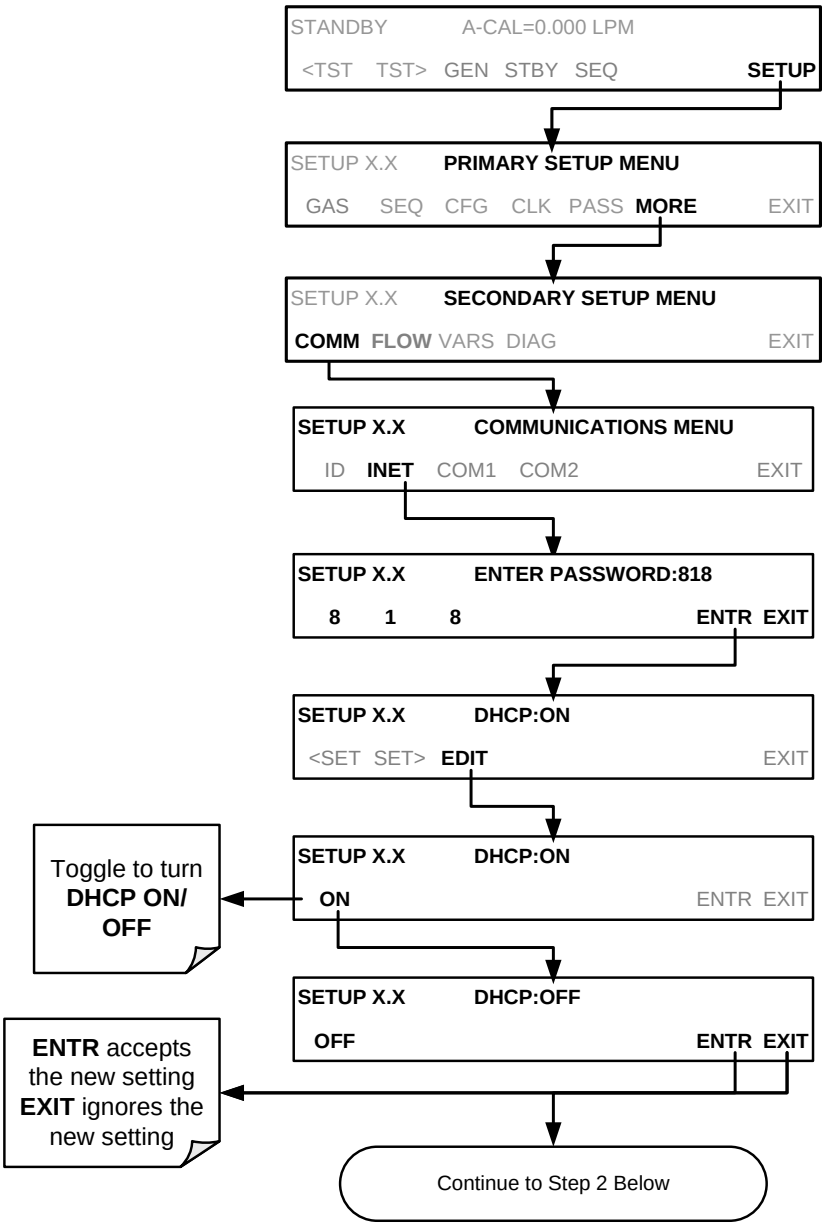


5.4.1.1. **Manually Configuring the Network IP Addresses**

There are several circumstances when you may need to manually set the Ethernet configuration:

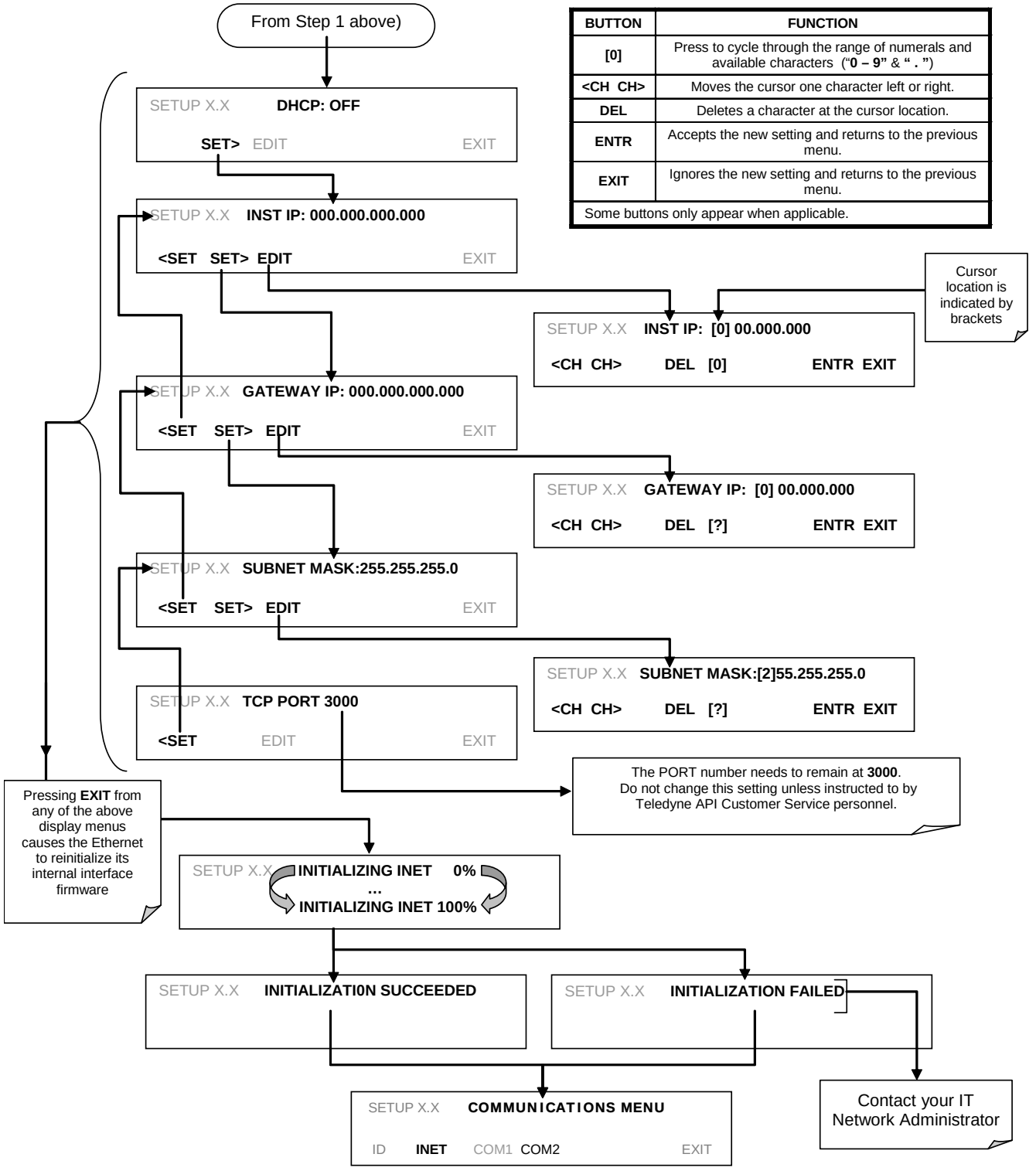
- Your LAN is not running a DHCP software package,
- The DHCP software is unable to initialize the calibrator's interface;
- You wish to configure the interface with a specific IP address, such as for a permanent Ethernet connection..

Manually configuring the Ethernet interface requires that you first turn DHCP to OFF before setting the **INSTRUMENT IP**, **GATEWAY IP** and **SUBNET MASK** parameters:



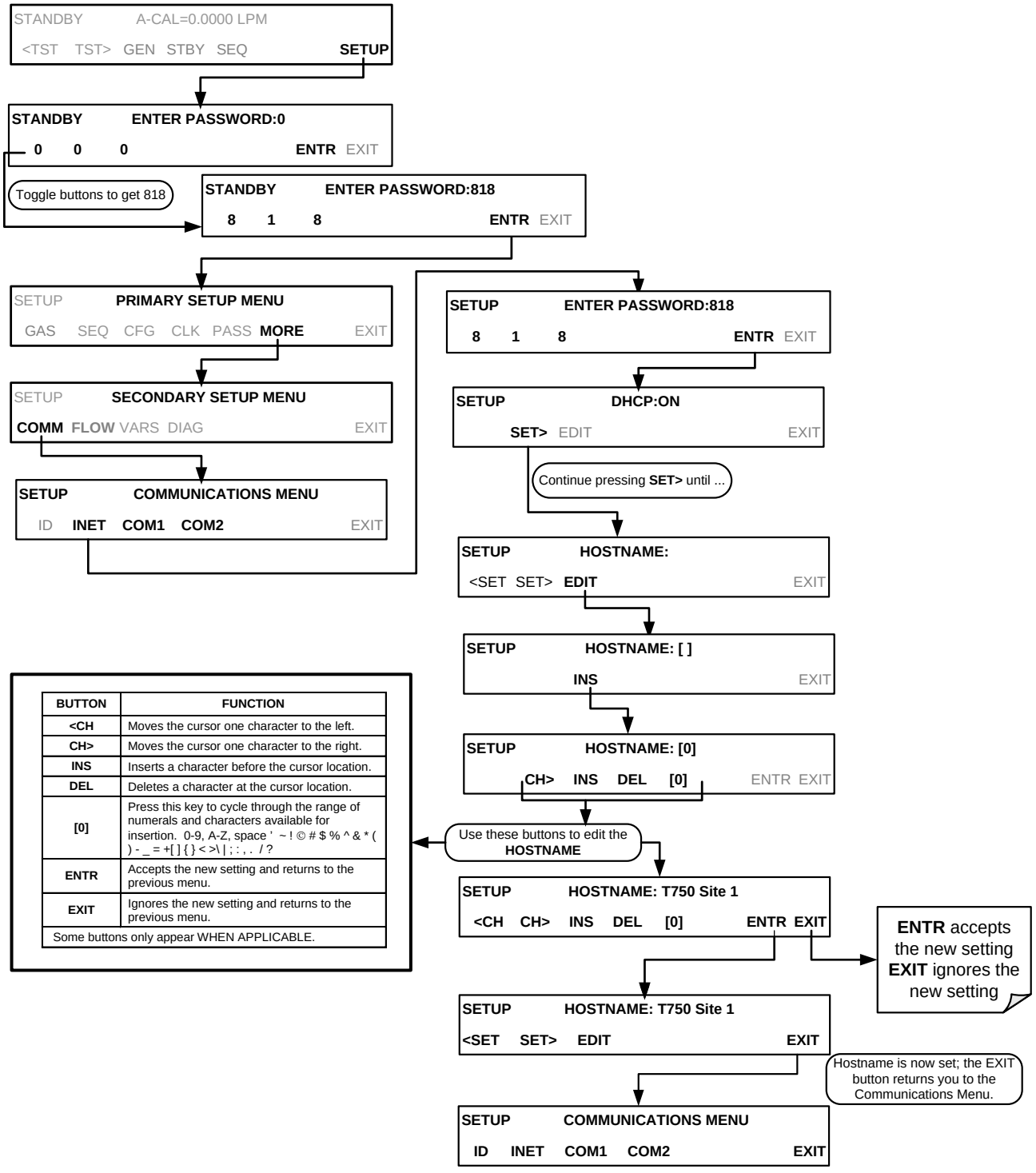
Internet Configuration Touchscreen Button Functions

BUTTON	FUNCTION
[0]	Press to cycle through the range of numerals and available characters ("**0 – 9"** & **" . "**)
<CH CH>	Moves the cursor one character left or right.
DEL	Deletes a character at the cursor location.
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.
Some buttons only appear when applicable.	



5.4.2. CHANGING THE CALIBRATOR'S HOSTNAME

The **HOSTNAME** is the name by which the calibrator appears on your network. The default name for all Teledyne API's T750 calibrators is **T750**. To change this name (particularly if you have more than one T750 calibrator on your network), press.

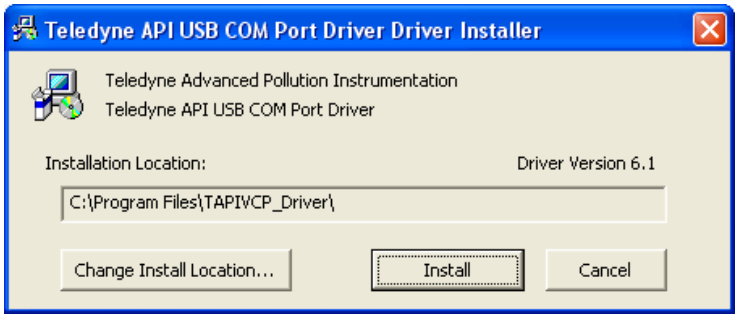


BUTTON	FUNCTION
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[0]	Press this key to cycle through the range of numerals and characters available for insertion. 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 buttons only appear WHEN APPLICABLE.	

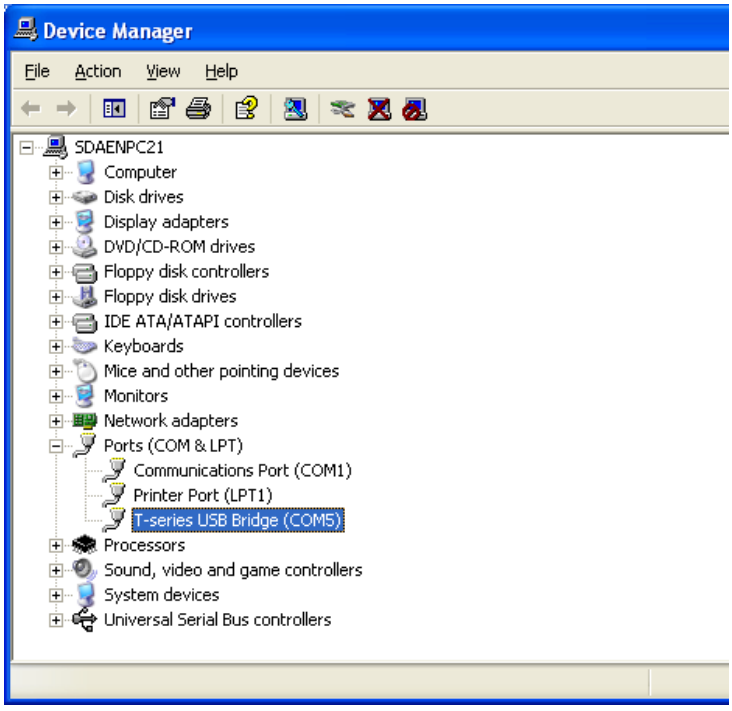
5.4.3. USB PORT (OPTION) FOR REMOTE ACCESS

The analyzer can be operated through a personal computer by downloading the TAPI 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.

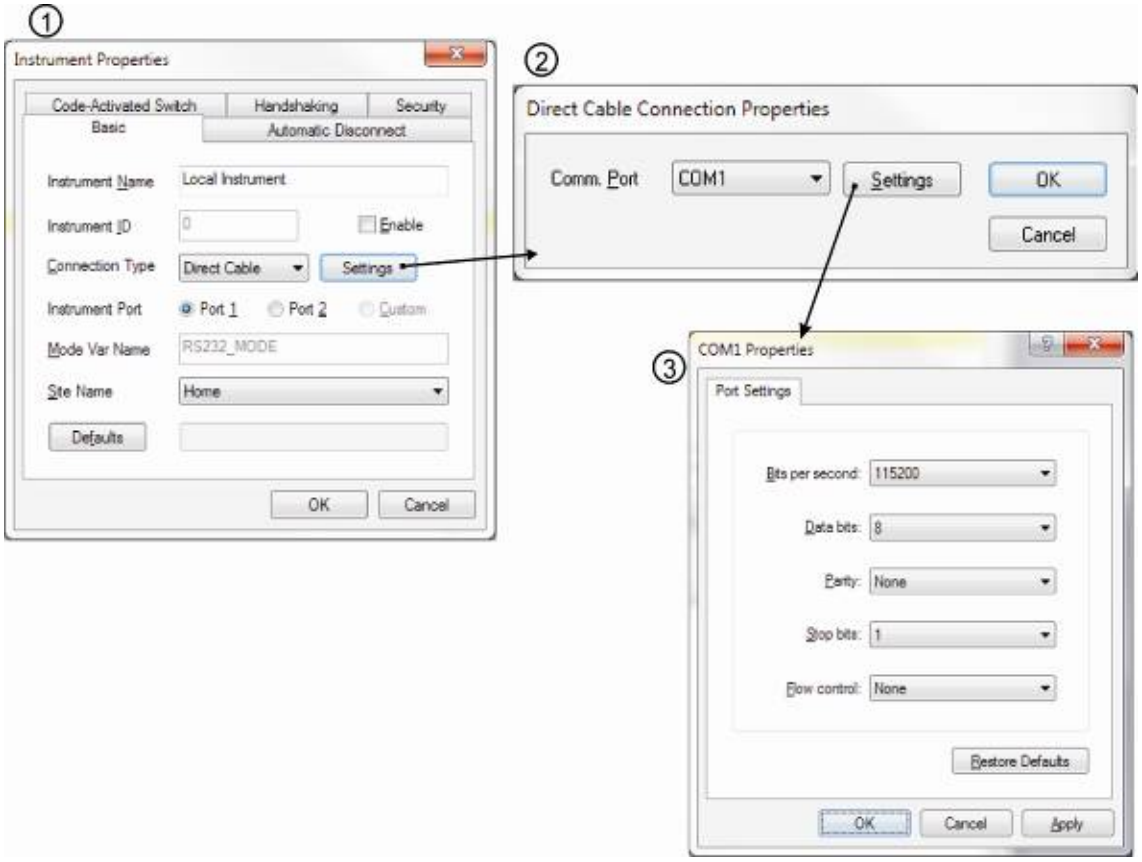
5. In the instrument's SETUP>MORE>COMM>COM2 menu, make the following settings:

   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		

6. 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 the baud rates of the instrument and the PC match; check the PC baud rate and change if needed.**
- **Using the USB port disallows use of the communications and output panel COM2 port except for multidrop communication.**

6. REMOTE OPERATION

This section provides information needed when using external digital and serial I/O for remote operation. It assumes that the electrical connections have been made as described in Section3.4.1

The T750 can be remotely configured, calibrated or queried for stored data through the communications and output panel serial ports, via either **Computer mode** (using a personal computer with a dedicated interface program) or **Interactive mode** (using a terminal emulation program).

6.1. COMPUTER MODE

Computer mode is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM.

6.1.1. REMOTE CONTROL VIA APICOM

APICOM is an easy-to-use, yet powerful interface program that allows the user to access and control any of Teledyne API's 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 T750 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's LCD touchscreen 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.
- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance, and trouble-shooting. Figure 6-1 shows an example of APICOM's main interface, which emulates the look and functionality of the instrument's actual LCD touchscreen. Refer to the APICOM manual available for download from http://www.teledyne-api.com/software/apicom/.

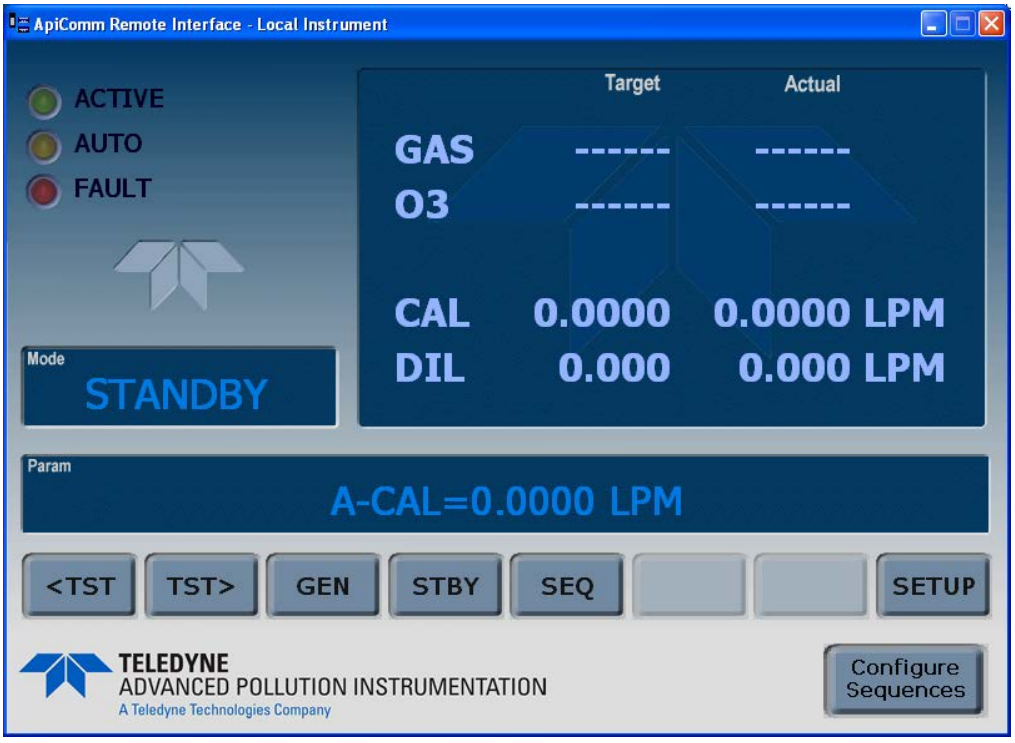


Figure 6-1: APICOM Remote Control Program Interface

6.2. INTERACTIVE MODE

Interactive mode is used with a terminal emulation programs or a "dumb" computer terminal.

6.2.1. REMOTE CONTROL VIA A TERMINAL EMULATION PROGRAM

Start a terminal emulation program such as HyperTerminal. All configuration commands must be created following a strict syntax or be pasted in from an existing text file, which was edited offline and then uploaded through a specific transfer procedure. The commands that are used to operate the analyzer in this mode are listed in Table 6-1.

6.2.1.1. Help Commands in Interactive Mode

Table 6-1: Terminal Mode Software Commands

COMMAND	Function
Control-T	Switches the calibrator 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 calibrator 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

COMMAND	Function
	be sent to the calibrator to be executed until this is done. On personal computers, this is achieved by pressing the ENTER button.
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 calibrator is only necessary if multiple calibrators 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.

6.2.1.2. **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 6-2 and Appendix A-6.

[ID] is the machine identification number (Section4.7.1). Example: the Command "? 700" 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 700.

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-6 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 button on a computer).

Table 6-2: Teledyne API Serial I/O Command Types

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

6.2.1.3. **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. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

6.2.1.4. **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 (Section 5.2.1, Table 5-1).

Status reports include warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the possible messages, and this for information on controlling the instrument through the RS-232 interface.

6.2.1.5. **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 6-2.
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 calibrator ID, a number with 1 to 4 digits.
MESSAGE	is the message content that may contain warning messages, test measurements, 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 LCD touchscreen 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.

6.3. REMOTE ACCESS BY MODEM

The T750 can be connected to a modem for remote access. This requires a cable between the calibrator's COMM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

Once the cable has been connected, check to ensure that:

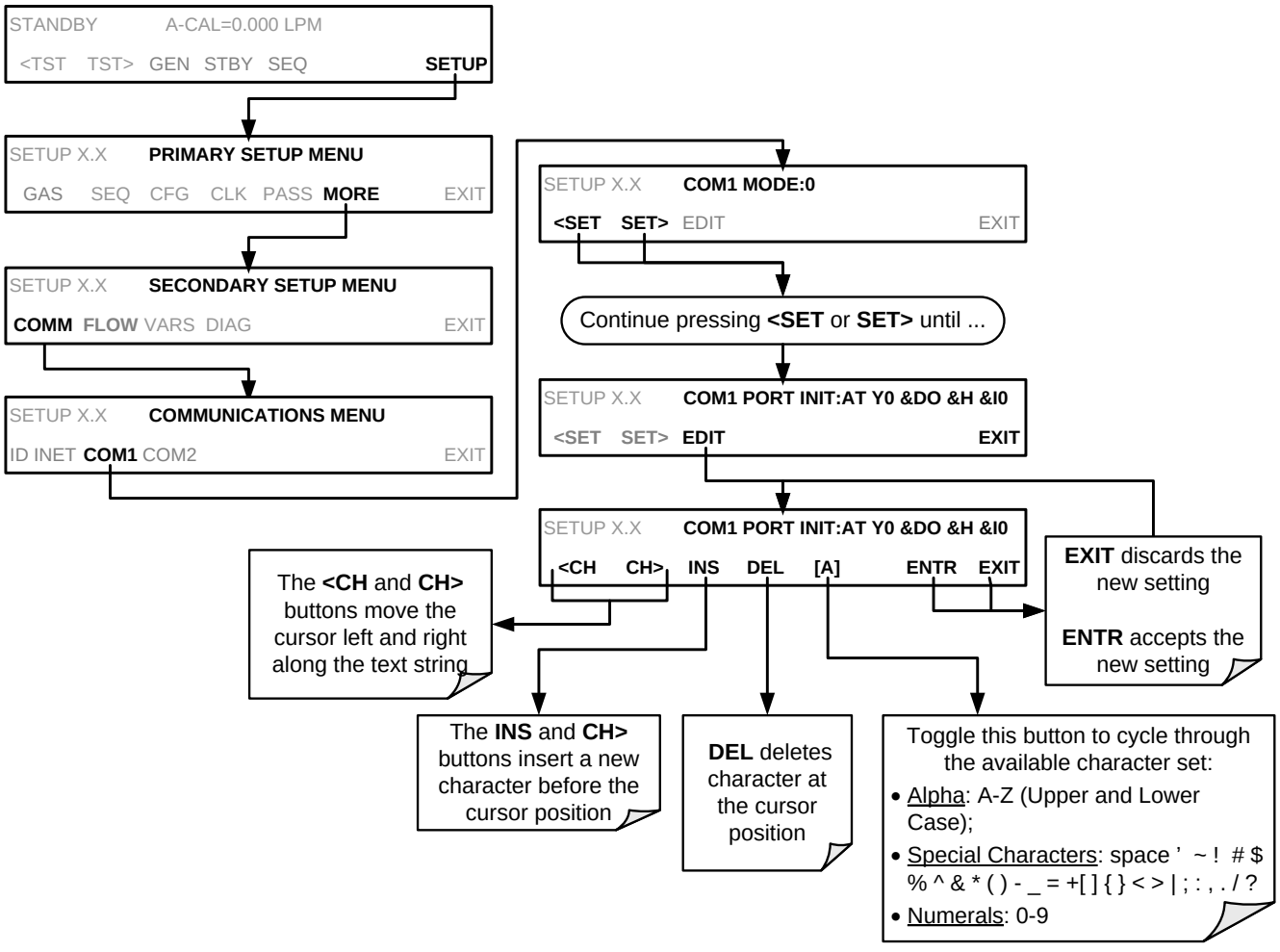
- The DTE-DCE is in the DCE position.
- The T750 COMM port is set for a baud rate that is compatible with the modem.
- The Modem is designed to operate with an 8-bit word length with one stop bit.
- The M**ODEM ENABLE** communication mode is turned **ON** (Mode 64, see Section 5.2.1).

Once this is completed, the appropriate setup command line for your modem can be entered into the calibrator. The default setting for this feature is:

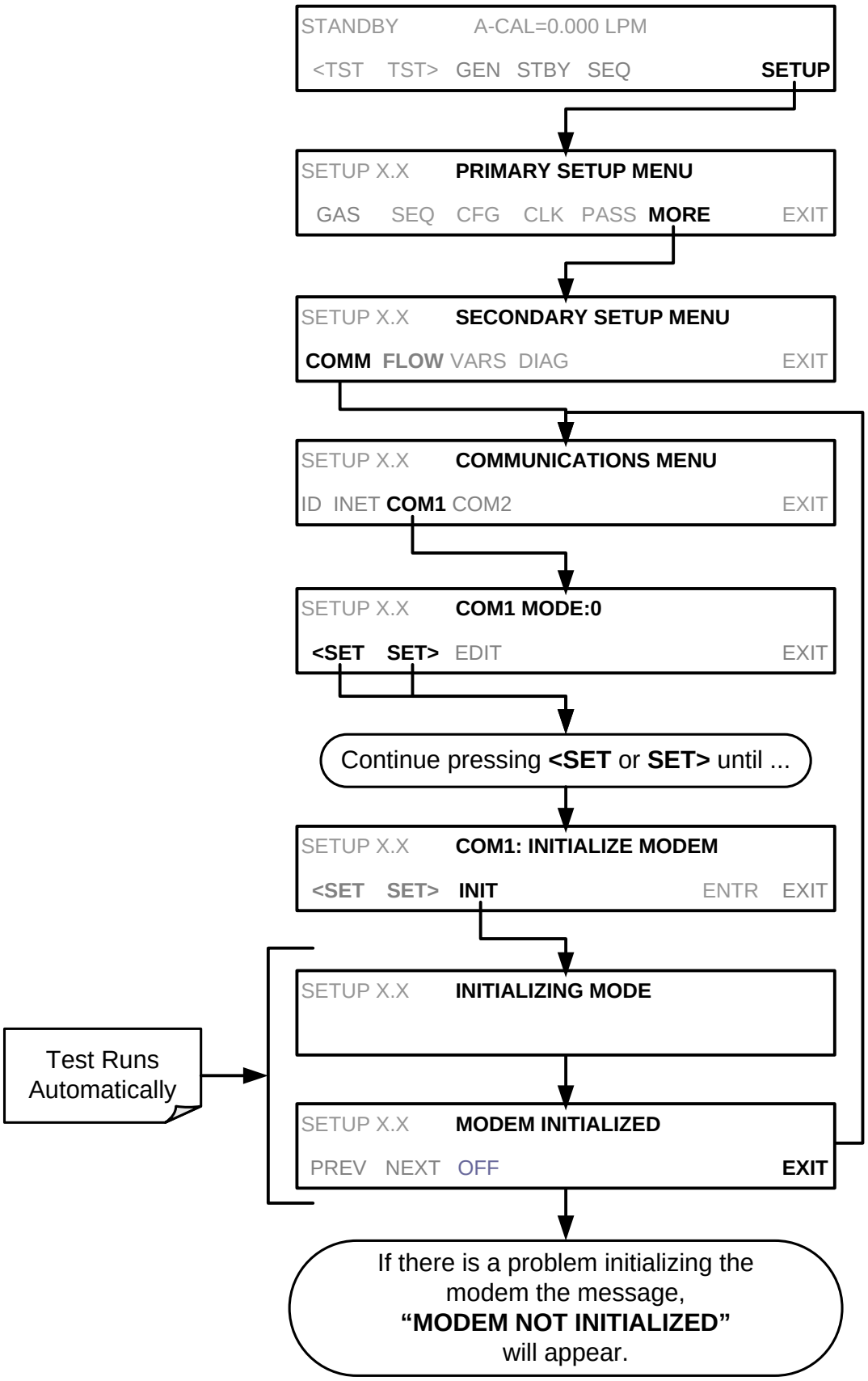
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0

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

To change this setting, press:



To initialize the modem, press:



6.4. PASSWORD SECURITY FOR SERIAL REMOTE COMMUNICATIONS

In order to provide security for remote access of the T750, 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** (Mode 4, Section 5.2.1). 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 T750 calibrator 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.

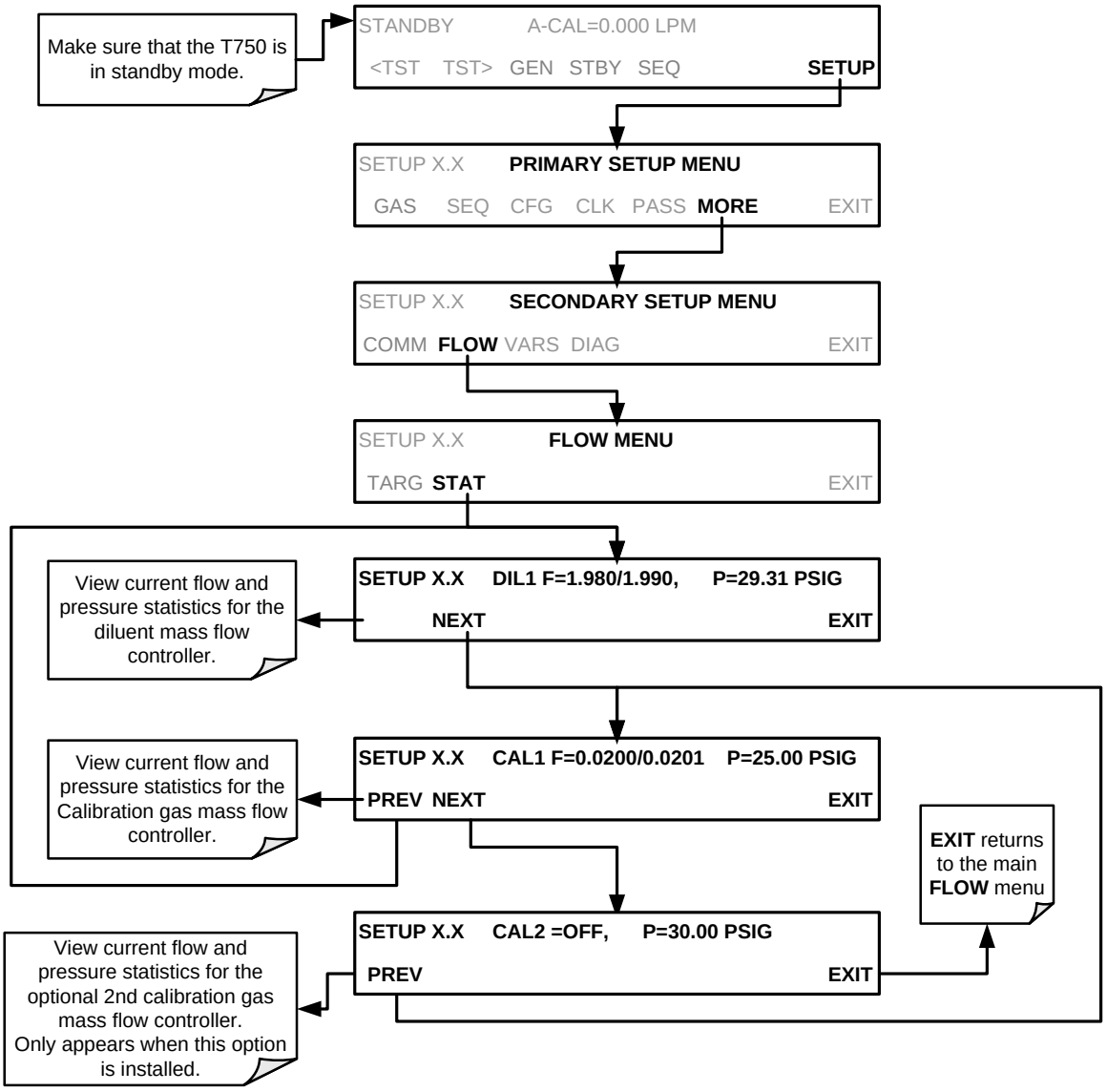
7. CALIBRATION AND VERIFICATION

Basic electronic calibration of the T750 Portable Calibrator is performed at the factory. Normally there is no need to perform this factory calibration in the field however, the performance of several of the instrument's key subsystems should be verified periodically and if necessary adjusted. These subsystems are:

- Mass Flow Controllers: The accuracy of the mass flow controller outputs is intrinsic to achieving the correct calibration mixture concentrations, therefore the accuracy of their output should be checked and if necessary adjusted every 6 months (see Sections 7.1 and 7.2).
- O_3 Photometer: If your T750 is equipped with the optional O_3 photometer its performance should be periodically verified against and external transfer standard (see Section 7.3).
- O_3 Generator: If your T750 is equipped with the optional O_3 generator, it should be periodically calibrated (see Section 7.4).

7.1. VIEWING THE PERFORMANCE STATISTICS FOR THE T750'S MFC'S

It is possible to view the target flow rate, actual flow rate and actual gas pressure for each MFC via the **FLOW** submenu in the T750 calibrator (in real time). To access this information, press:


Make sure that the T750 is in standby mode.
STANDBY A-CAL=0.000 LPM
<TST TST> GEN STBY SEQ SETUP
SETUP X.X PRIMARY SETUP MENU
GAS SEQ CFG CLK PASS MORE EXIT
SETUP X.X SECONDARY SETUP MENU
COMM FLOW VARS DIAG EXIT
SETUP X.X FLOW MENU
TARG STAT EXIT
View current flow and pressure statistics for the diluent mass flow controller.
SETUP X.X DIL1 F=1.980/1.990, P=29.31 PSIG
NEXT EXIT
View current flow and pressure statistics for the Calibration gas mass flow controller.
SETUP X.X CAL1 F=0.0200/0.0201 P=25.00 PSIG
PREV NEXT EXIT
EXIT returns to the main FLOW menu
View current flow and pressure statistics for the optional 2nd calibration gas mass flow controller. Only appears when this option is installed.
SETUP X.X CAL2 =OFF, P=30.00 PSIG
PREV EXIT

In the displays associated with the **FLOW → STAT** submenu:

- The numbers after "F=" are the flow.
  - The first number is the target flow.
  - The second is the actual flow.
- The number after "P=" is pressure in PSIG.
- If an MFC is off, its flows are displayed as OFF.

7.2. CALIBRATING THE OUTPUT OF THE T750'S MFC'S

A table exists in the memory of the T750's for each MFC that sets the output of the MFC at each of 20 equally spaced control points along its entire performance range. This table may be accesses via the **DIAG → MFC CONFIGURATION** submenu (see Section 7.2.2).

For each calibration point, the following is displayed:

- The drive voltage in 20 equal, incremental steps from 0 mVDC to 5000 mVDC;
- The expected flow rate corresponding to each drive voltage point (each equal to1/20th of the full scale for the selected mass flow controller).

This table can also be used to calibrate the output of the MFCs by adjusting either the control voltage of a point or its associated flow output value (see Section 7.2.2).

Table 7-1: Examples of MFC Calibration Points

CAL POINT	DRIVE VOLTAGE	MFC FULL SCALE			
		1.0 LPM	3.0 LPM	5.0 LPM	10.0 LPM
		MFC TARGET OUTPUT			
0	000 mV	0.000	0.000	0.000	0.000
1	250 mV	0.050	0.150	0.250	0.500
2	500 mV	0.100	0.300	0.500	1.000
3	750 mV	0.150	0.450	0.750	1.500
4	1000 mV	0.200	0.600	1.000	2.000
5	1250 mV	0.250	0.750	1.250	2.500
6	1500 mV	0.300	0.900	1.500	3.000
7	1750 mV	0.350	1.050	1.750	3.500
8	2000 mV	0.400	1.200	2.000	4.000
9	2250 mV	0.450	1.350	2.250	4.500
10	2500 mV	0.500	1.500	2.500	5.000
11	2750 mV	0.550	1.650	2.750	5.500
12	3000 mV	0.600	1.800	3.000	6.000
13	3250 mV	0.650	1.950	3.250	6.500
14	3500 mV	0.700	2.100	3.500	7.000
15	3750 mV	0.750	2.250	3.750	7.500
16	4000 mV	0.800	2.400	4.000	8.000
17	4250 mV	0.850	2.550	4.250	8.500
18	4500 mV	0.900	2.700	4.500	9.000
19	4750 mV	0.950	2.850	4.750	9.500
20	5000 mV	1.000	3.000	5.000	10.000

7.2.1. SETUP FOR VERIFICATION AND CALIBRATION OF THE T750'S MFC'S

Note **A separate flow meter is required for the procedure.**

1. Turn off the T750 Portable Calibrator.
2. Open the panels to the T750 calibrator.
3. Attach the flow meter directly to the output port of the MFC to be checked/tested.

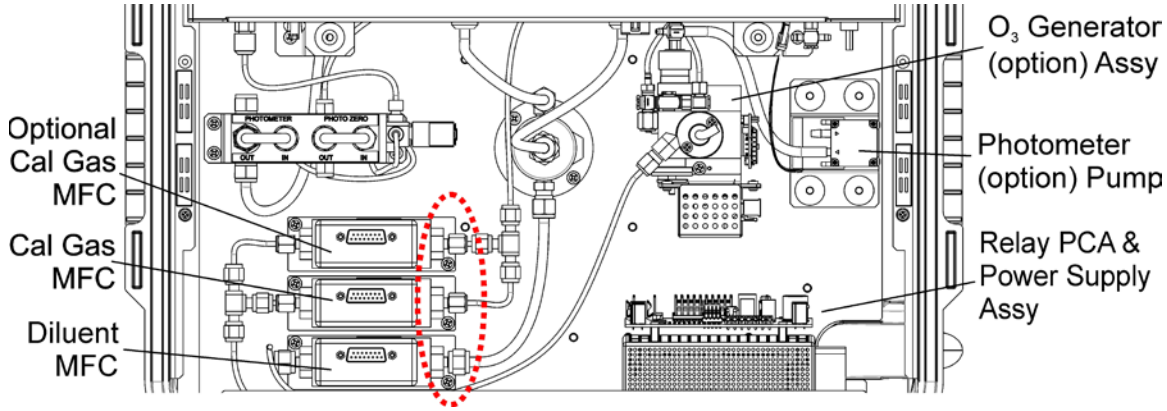
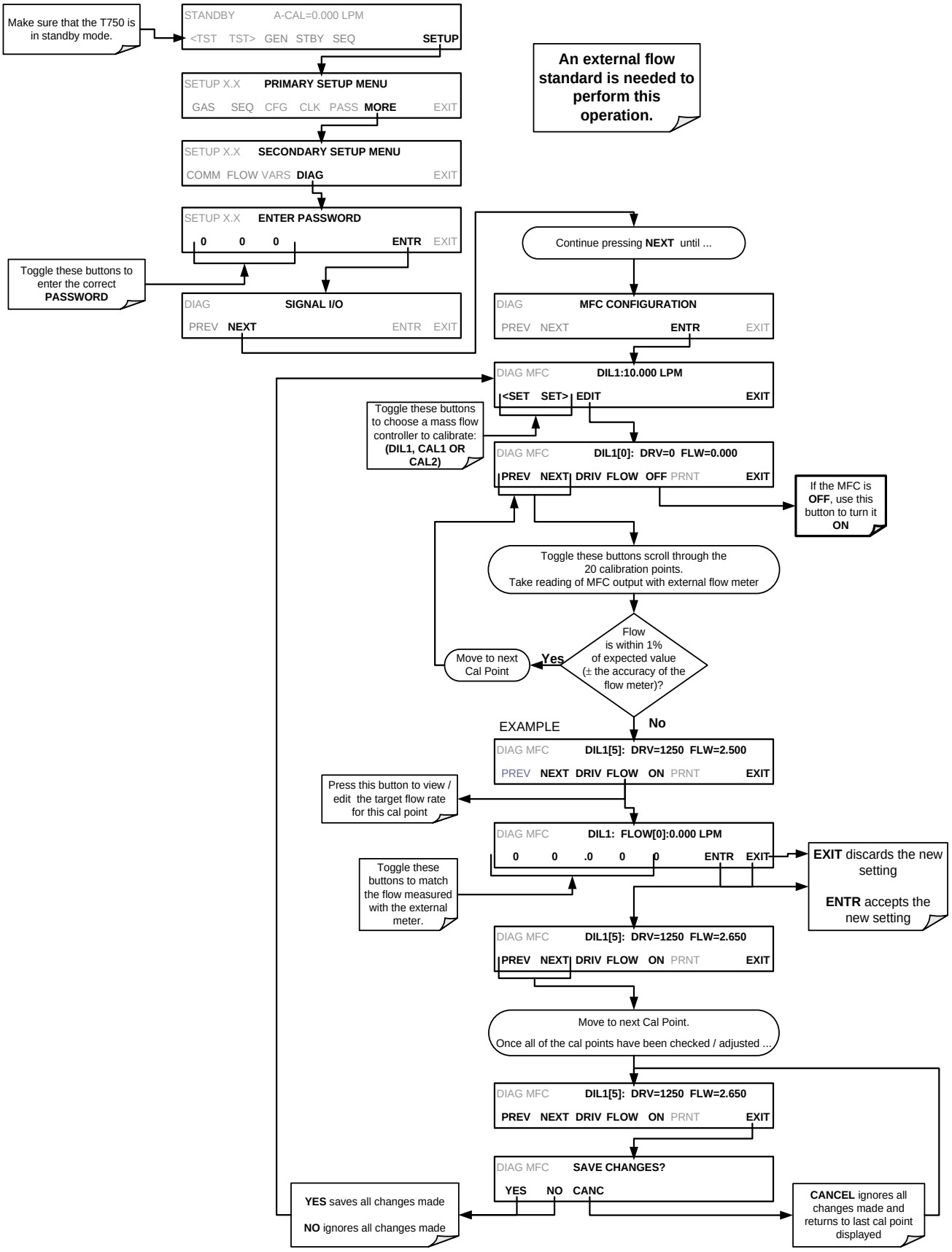


Figure 7-1: Location of MFC Outlet Ports

4. Turn the T750 Portable Calibrator ON.

7.2.2. VERIFYING AND CALIBRATING THE T750'S MFC'S

Once the external flow meter is connected to the output of the MFC being verified/calibrated, perform the following steps:


Make sure that the T750 is in standby mode.
STANDBY A-CAL=0.000 LPM
<TST TST> GEN STBY SEQ SETUP
SETUP X.X PRIMARY SETUP MENU
GAS SEQ CFG CLK PASS MORE EXIT
SETUP X.X SECONDARY SETUP MENU
COMM FLOW VARS DIAG EXIT
SETUP X.X ENTER PASSWORD
0 0 0 ENTR EXIT
Toggle these buttons to enter the correct PASSWORD
DIAG SIGNAL I/O
PREV NEXT ENTR EXIT
An external flow standard is needed to perform this operation.
Continue pressing NEXT until ...
DIAG MFC CONFIGURATION
PREV NEXT ENTR EXIT
DIAG MFC DIL1:10.000 LPM
<SET SET> EDIT EXIT
Toggle these buttons to choose a mass flow controller to calibrate: (DIL1, CAL1 OR CAL2)
DIAG MFC DIL1[0]: DRV=0 FLW=0.000
PREV NEXT DRIV FLOW OFF PRNT EXIT
If the MFC is OFF, use this button to turn it ON
Toggle these buttons scroll through the 20 calibration points. Take reading of MFC output with external flow meter
Flow is within 1% of expected value (± the accuracy of the flow meter)?
Yes
Move to next Cal Point
No
EXAMPLE
DIAG MFC DIL1[5]: DRV=1250 FLW=2.500
PREV NEXT DRIV FLOW ON PRNT EXIT
Press this button to view / edit the target flow rate for this cal point
DIAG MFC DIL1: FLOW[0]:0.000 LPM
0 0 .0 0 0 ENTR EXIT
Toggle these buttons to match the flow measured with the external meter.
EXIT discards the new setting
ENTR accepts the new setting
DIAG MFC DIL1[5]: DRV=1250 FLW=2.650
PREV NEXT DRIV FLOW ON PRNT EXIT
Move to next Cal Point.
Once all of the cal points have been checked / adjusted ...
DIAG MFC DIL1[5]: DRV=1250 FLW=2.650
PREV NEXT DRIV FLOW ON PRNT EXIT
DIAG MFC SAVE CHANGES?
YES NO CANC
YES saves all changes made
NO ignores all changes made
CANCEL ignores all changes made and returns to last cal point displayed

7.3. VERIFYING AND CALIBRATING THE T750'S OPTIONAL O_3 PHOTOMETER

For calibrators equipped with the O_3 photometer, the accuracy of calibration mixtures involving O_3 produced by the T750 depends entirely on the accuracy of the photometer; therefore, it is very important that the photometer is operating properly and accurately. Section 7.3.1 shows the setup, and Section 7.3.2 shows the steps for verifying the O_3 photometer performance.

7.3.1. SETUP FOR VERIFYING O_3 PHOTOMETER PERFORMANCE

Note **This operation requires an external reference photometer.**

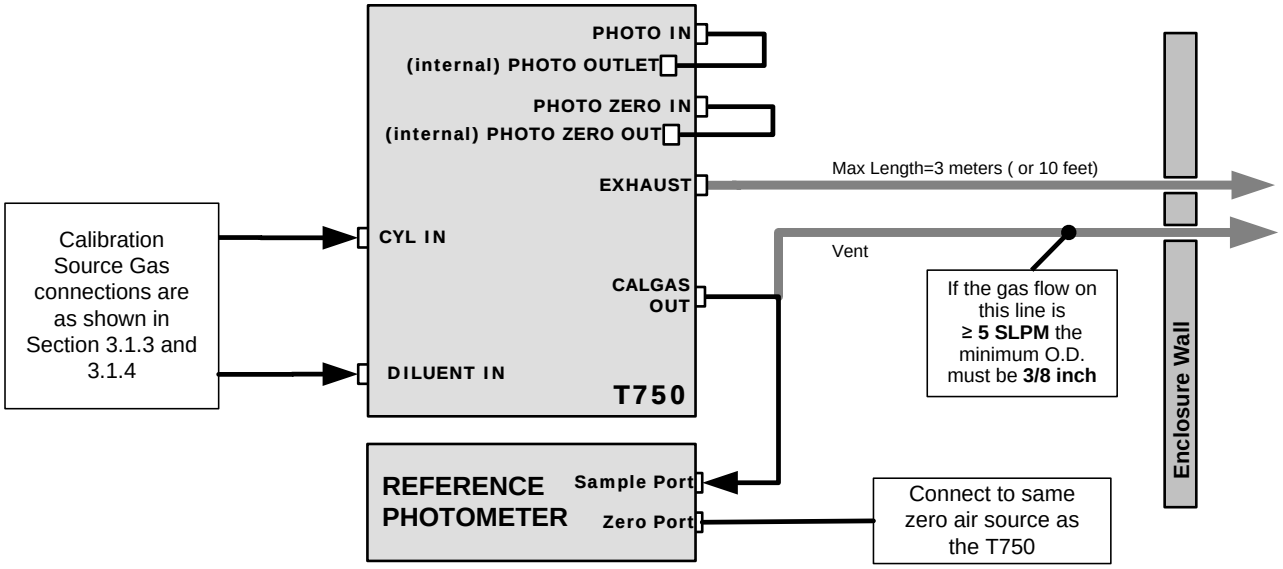
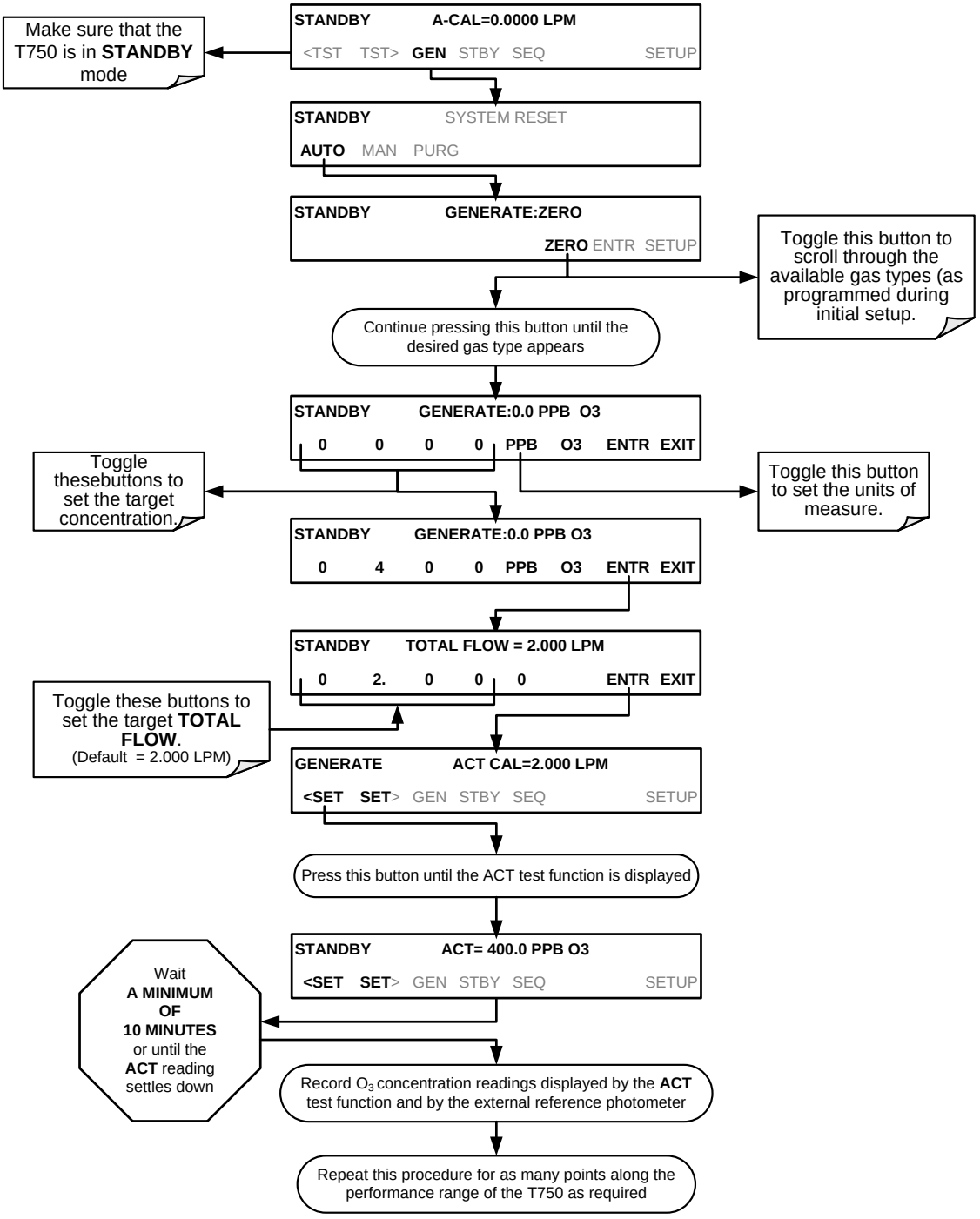


Figure 7-2: Set up for Verifying Optional O_3 Photometer

7.3.2. VERIFYING O_3 PHOTOMETER PERFORMANCE

To verify the performance of the T750's optional internal photometer perform the following steps:



Note **The readings recorded from the T750's ACT test function and the reference photometer should be within 1% of each other.**

7.3.3. SETUP FOR CALIBRATION OF THE O_3 PHOTOMETER

Note **This procedure requires external sources for zero air and O_3 as an external reference photometer.**

Calibrating the T750 calibrator's optional internal photometer requires a different set up than that used during the normal operation of the calibrator. There are two ways to make the connections between these instruments and the T750 calibrator: either with direct connections or calibration manifolds

7.3.3.1. Setup Using Direct Connections

Figure 7-3 shows the external zero air and O_3 sources as well as the reference photometer connected directly to the fixtures on the back of the T750 Calibrator.

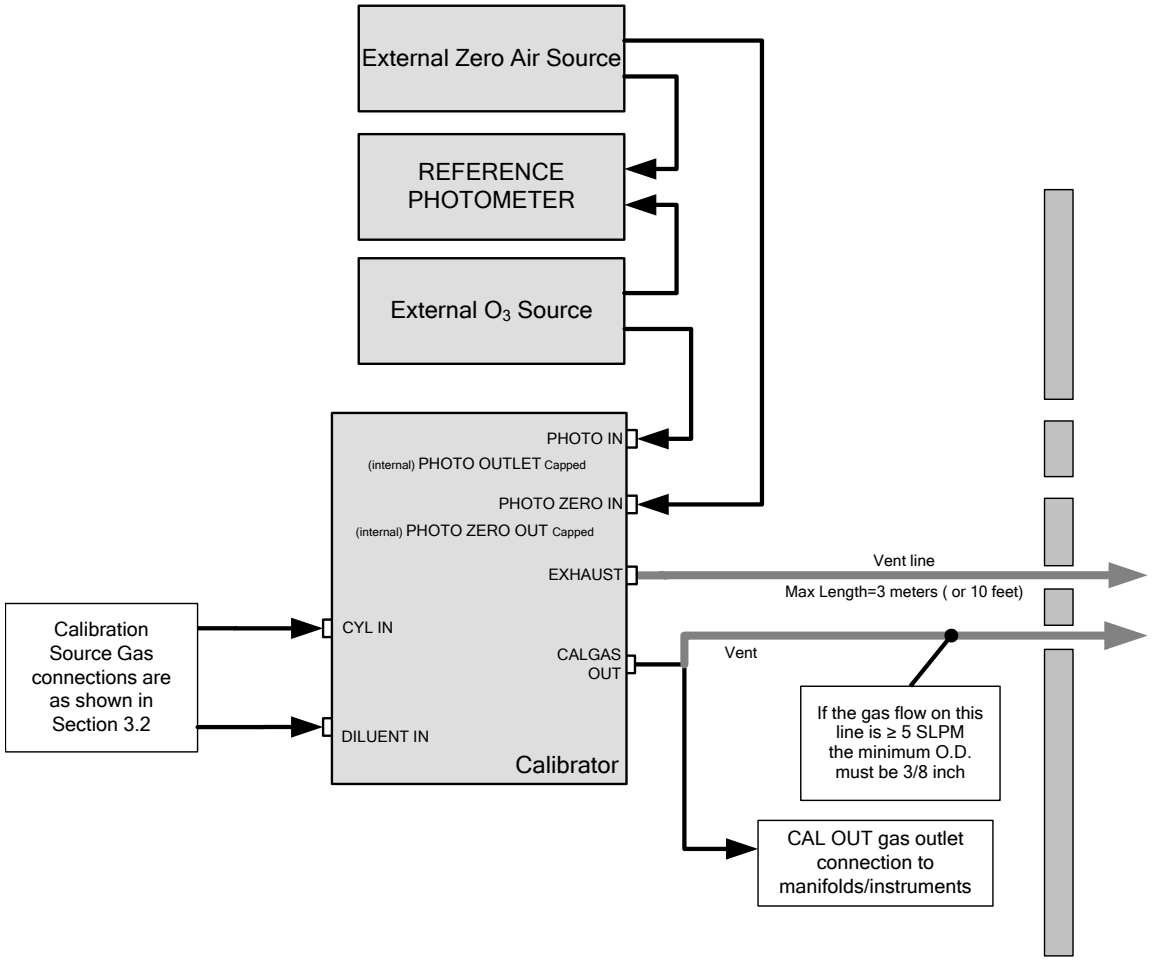


Figure 7-3: External Photometer Validation Setup – Direct Connections

Note **A Minimum of 1.1 LPM is required for the external zero air source.**

7.3.3.2. Setup Using a Calibration Manifold

Figure 7-4 shows the external zero air and O_3 sources as well as the reference photometer connected to the T750 Calibrator via calibration manifolds for both zero air and O_3.

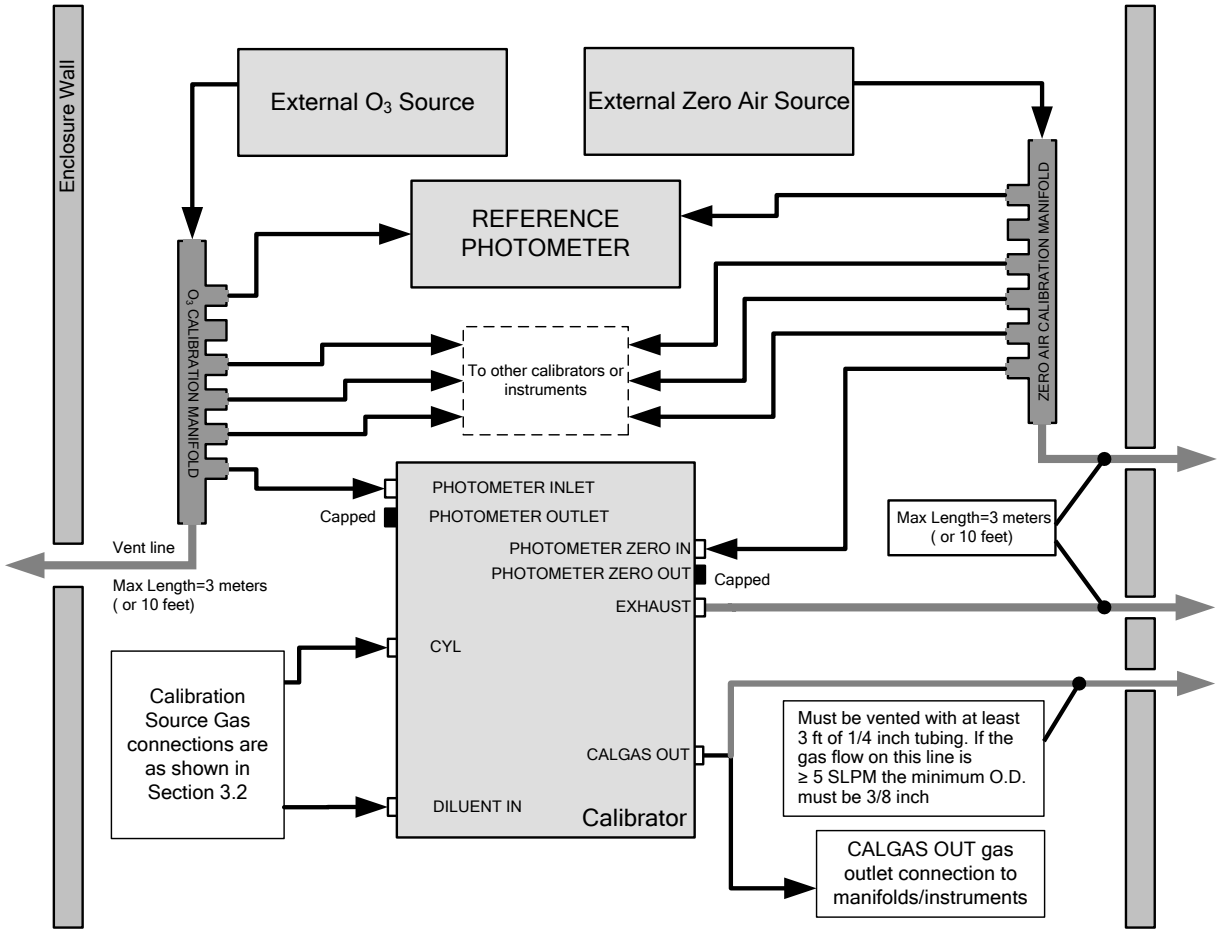


Figure 7-4: External Photometer Validation Setup with Calibration Manifolds

Note

The manifolds as shown in the above drawing are oriented to simplify the drawing. The actual orientation in your setup is with the ports facing upward. All unused ports should be capped. A Minimum of 1.1 LPM is required for the external zero air source.

7.3.3.3. Calibration Manifold Exhaust/Vent Line

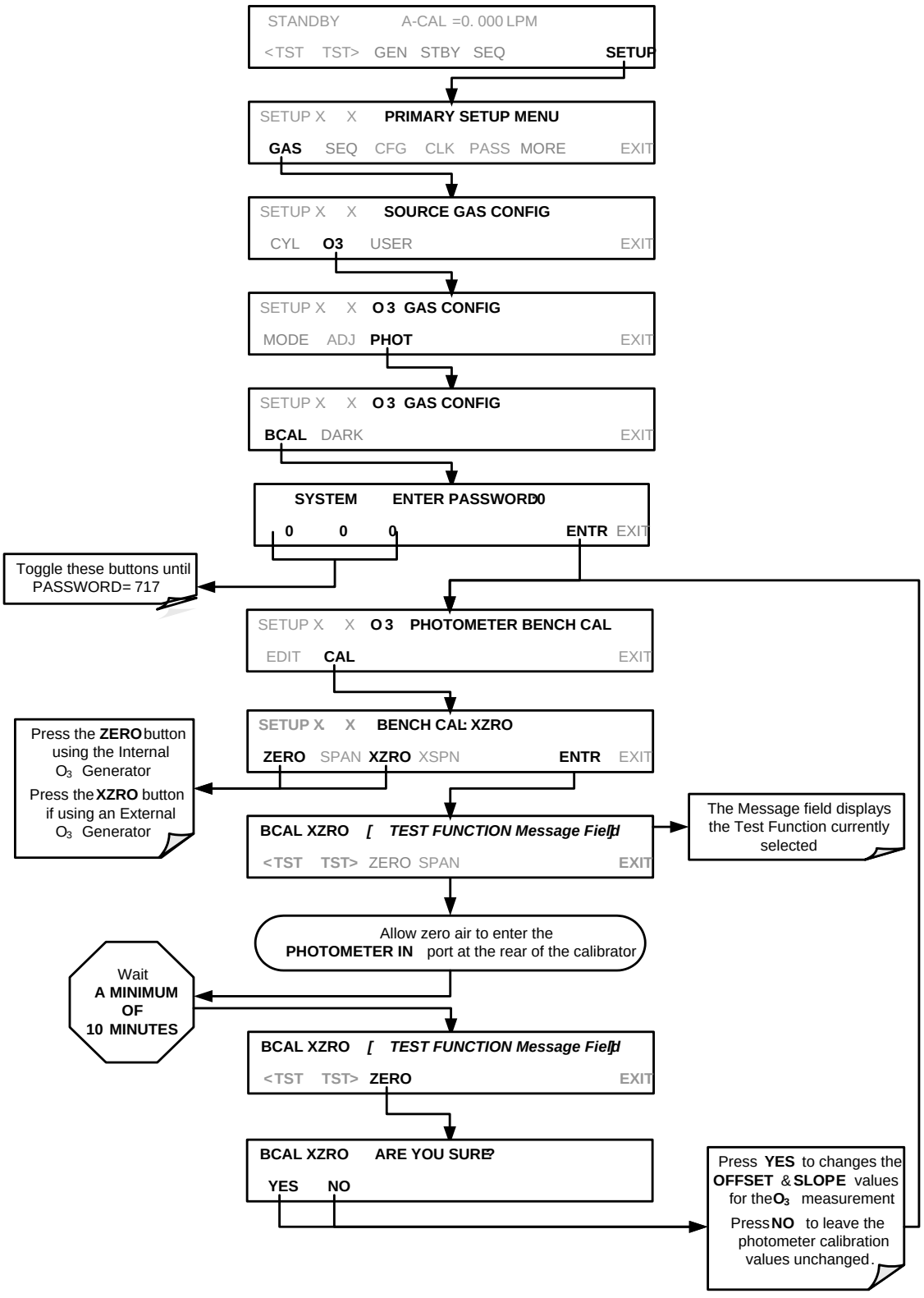
The manifold's excess gas should be vented to a suitable vent outside of the room. The internal diameter of this vent should be large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to ensure that no ambient air enters the manifold due to eddy currents or back diffusion.

7.3.4. PERFORMING AN O_3 PHOTOMETER EXTERNAL CALIBRATION

The following procedure sets values held in the calibrator's memory for zero point **OFFSET** and **SLOPE.**

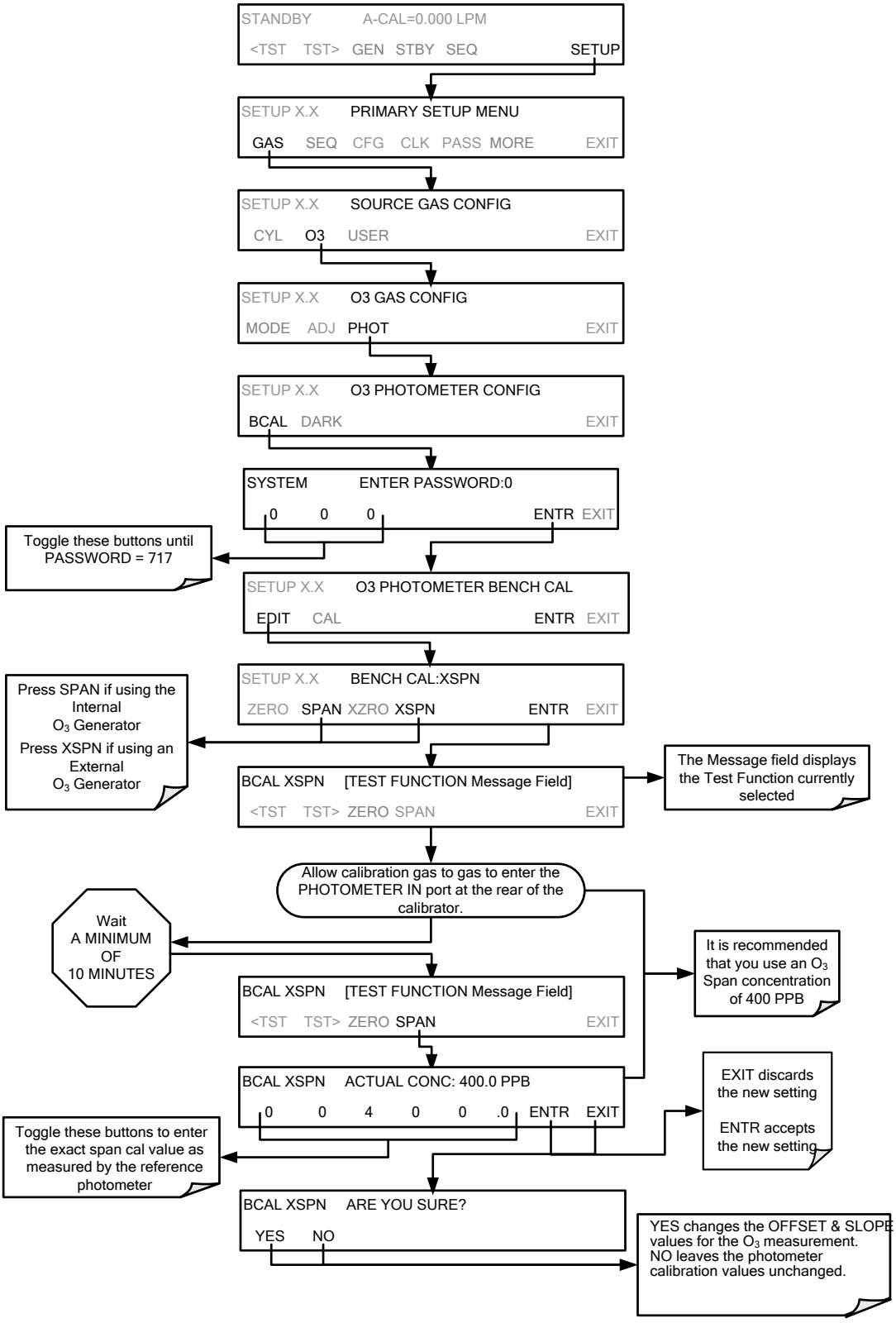
7.3.4.1. **Photometer Zero Calibration**

To set the zero point offset for the T750 Portable Calibrator's photometer, press:



7.3.4.2. **Photometer Span Calibration**

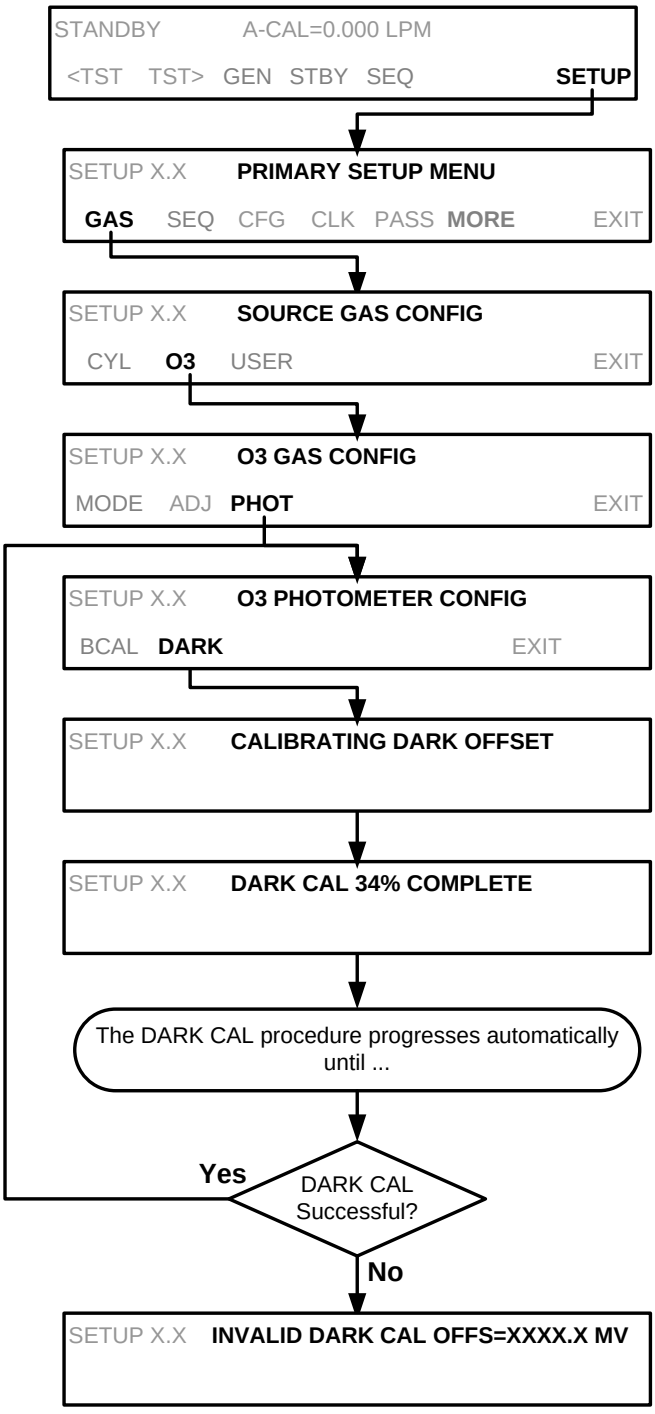
To set the response SLOPE for the T750 Portable Calibrator's photometer, press:



7.3.5. O_3 PHOTOMETER DARK CALIBRATION

The Dark Calibration Test turns off the Photometer UV Lamp and records any offset signal level of the UV Detector-Preamp-Voltage to Frequency Converter circuitry. This allows the instrument to compensate for any voltage levels inherent in the Photometer detection circuit that might affect the output of the detector circuitry and therefore the calculation of O_3 concentration.

To activate the Dark Calibration feature, press the following menu sequence:

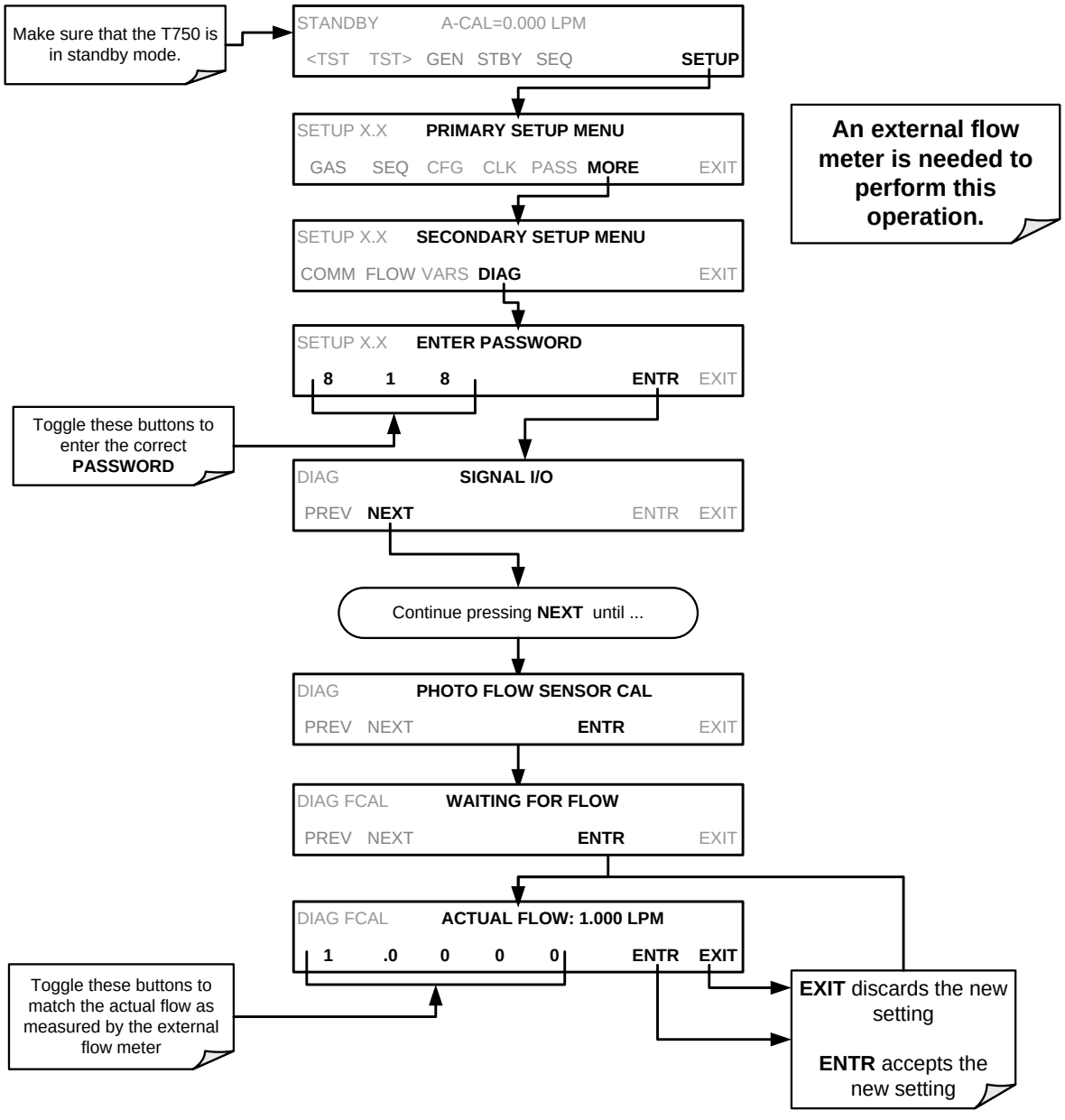


7.3.6. O_3 PHOTOMETER GAS FLOW CALIBRATION

Note **A separate flow meter is required for the procedure.**

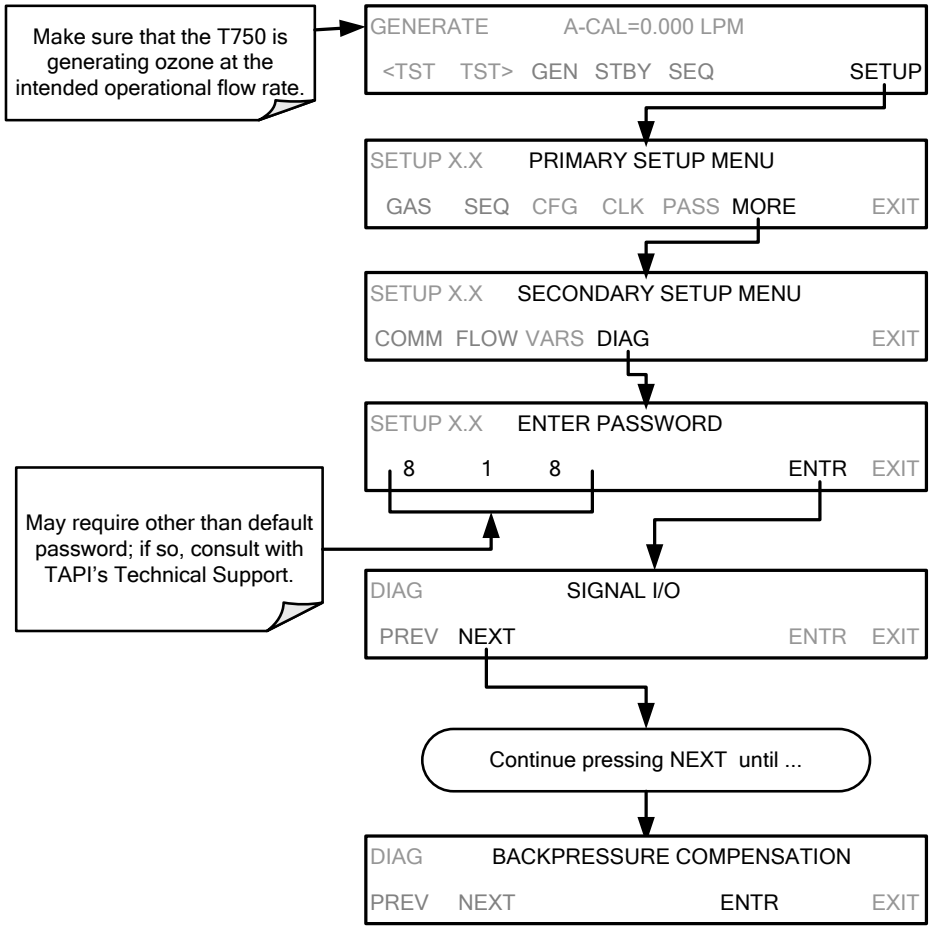
To calibrate the flow of gas through the T750 calibrator's optional photometer bench:

1. Turn OFF the T750 Portable Calibrator.
2. Attach the flow meter directly to the EXHAUST port of the T750 calibrator.
3. Turn the T750 Portable Calibrator ON.
4. Perform the following steps:



7.3.7. O_3 PHOTOMETER BACKPRESSURE COMPENSATION CALIBRATION

Any time there is a pneumatic configuration change, there is risk of impacting the internal measure/reference pressure. To compensate for this, a backpressure compensation calibration is required after each change. Set the calibrator to generate ozone at the flow rate intended for operation. While the instrument is generating ozone, go to the SETUP>MORE>DIAG>818*>…>BACKPRESSURE COMPENSATION menu and press ENTR to initiate the calibration; the operation will take a few minutes. (* earlier versions of the software may require a different password).



7.4. CALIBRATING THE O_3 GENERATOR

7.4.1. SETUP FOR VERIFICATION AND CALIBRATION OF THE O_3 GENERATOR

Note **An external reference photometer is required for the procedure.**

7.4.1.1. Setup Using Direct Connections

Figure 7-5 shows the reference photometer connected directly to the fixtures on the back of the T750 Calibrator.

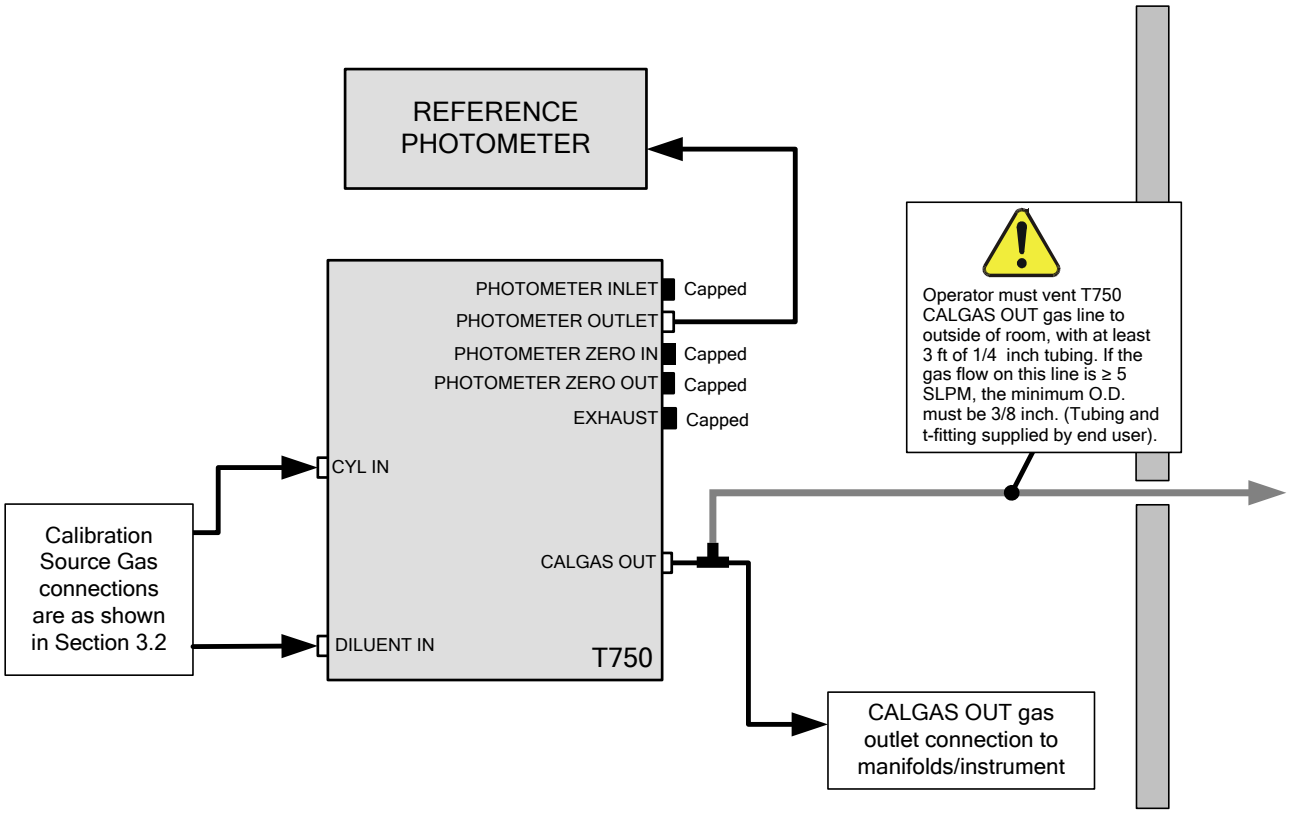
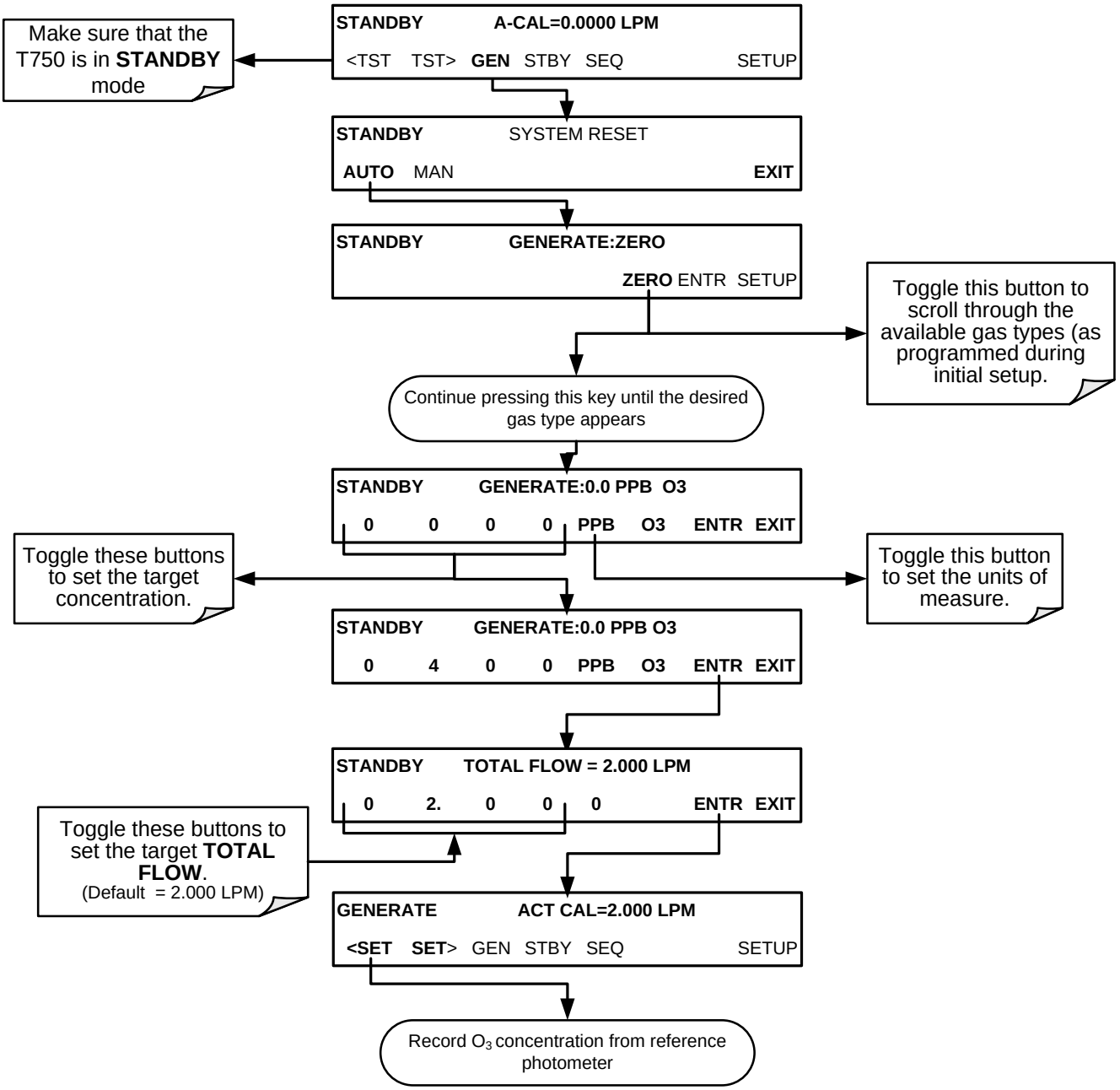


Figure 7-5: O_3 Generator Calibration Setup – Direct Connections

7.4.1.2. **Verifying O3 Generator Performance**

Using the set up shown in Figure 8-4, perform the following steps:



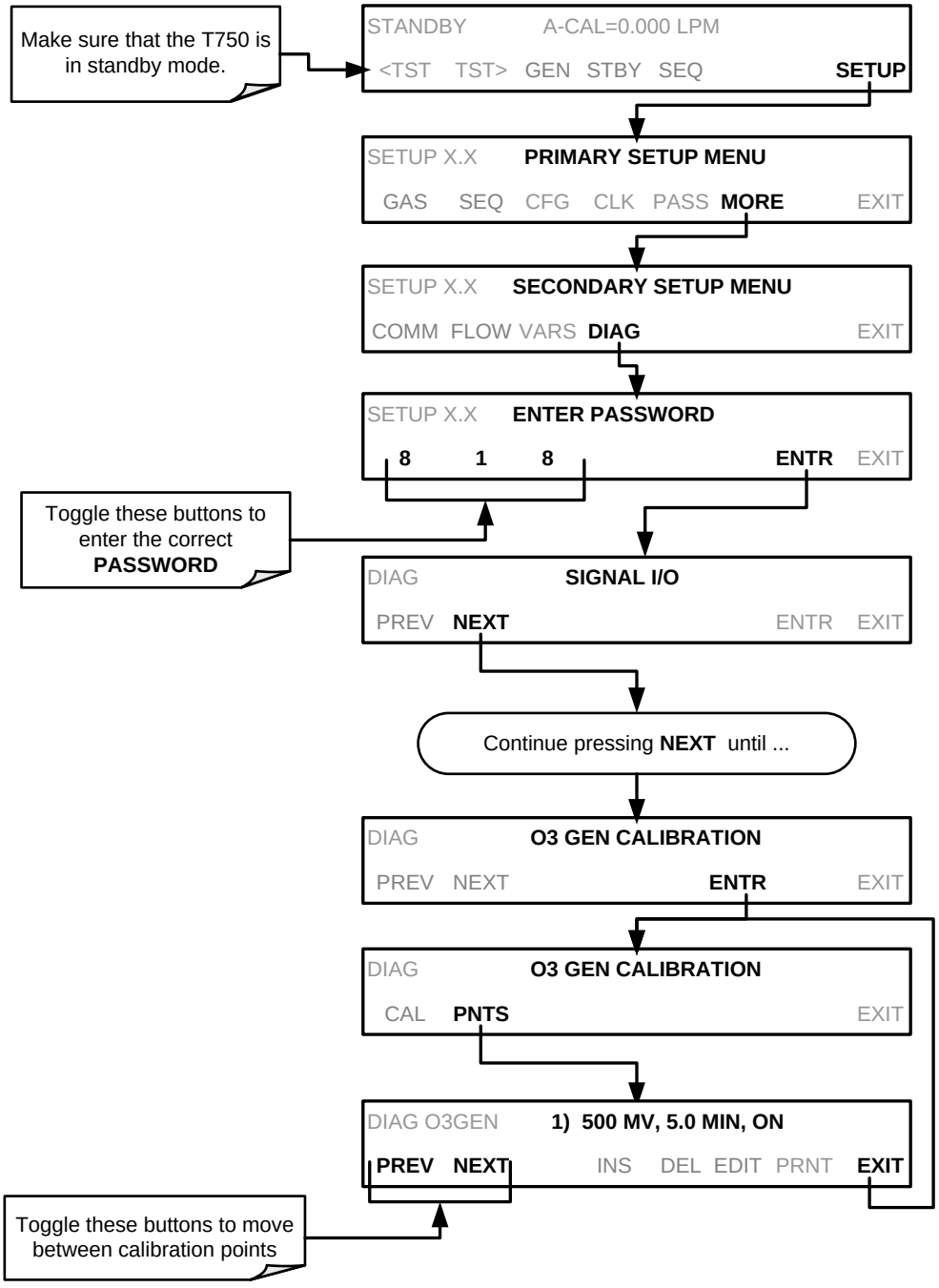
Note **The readings recorded from the T750's A-CAL test function and the reference photometer should be within 1% of each other.**

7.4.2. O_3 GENERATOR CALIBRATION PROCEDURE

The T750 calibrator's software includes a routine for automatically calibrating the O_3 generator. A table of drive voltages stored in the T750's memory is the basis for this calibration. For each point included in the table used by the T750 to calibrate the optional O_3 generator, the user can set a drive voltage and a dwell time for that point. Any individual point can also be turned OFF or ON.

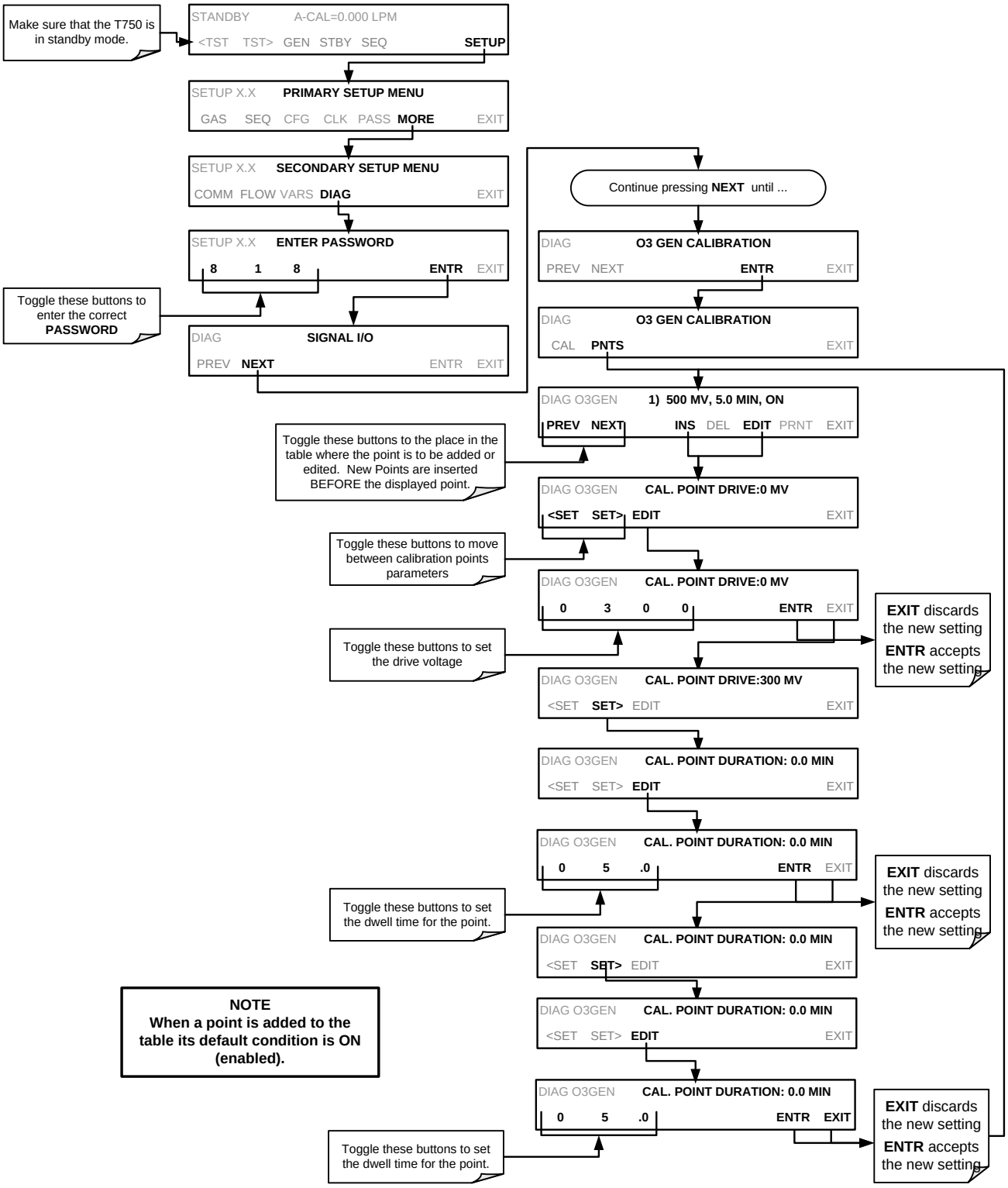
7.4.2.1. Viewing O_3 Generator Calibration Points

To view these calibration points, press:



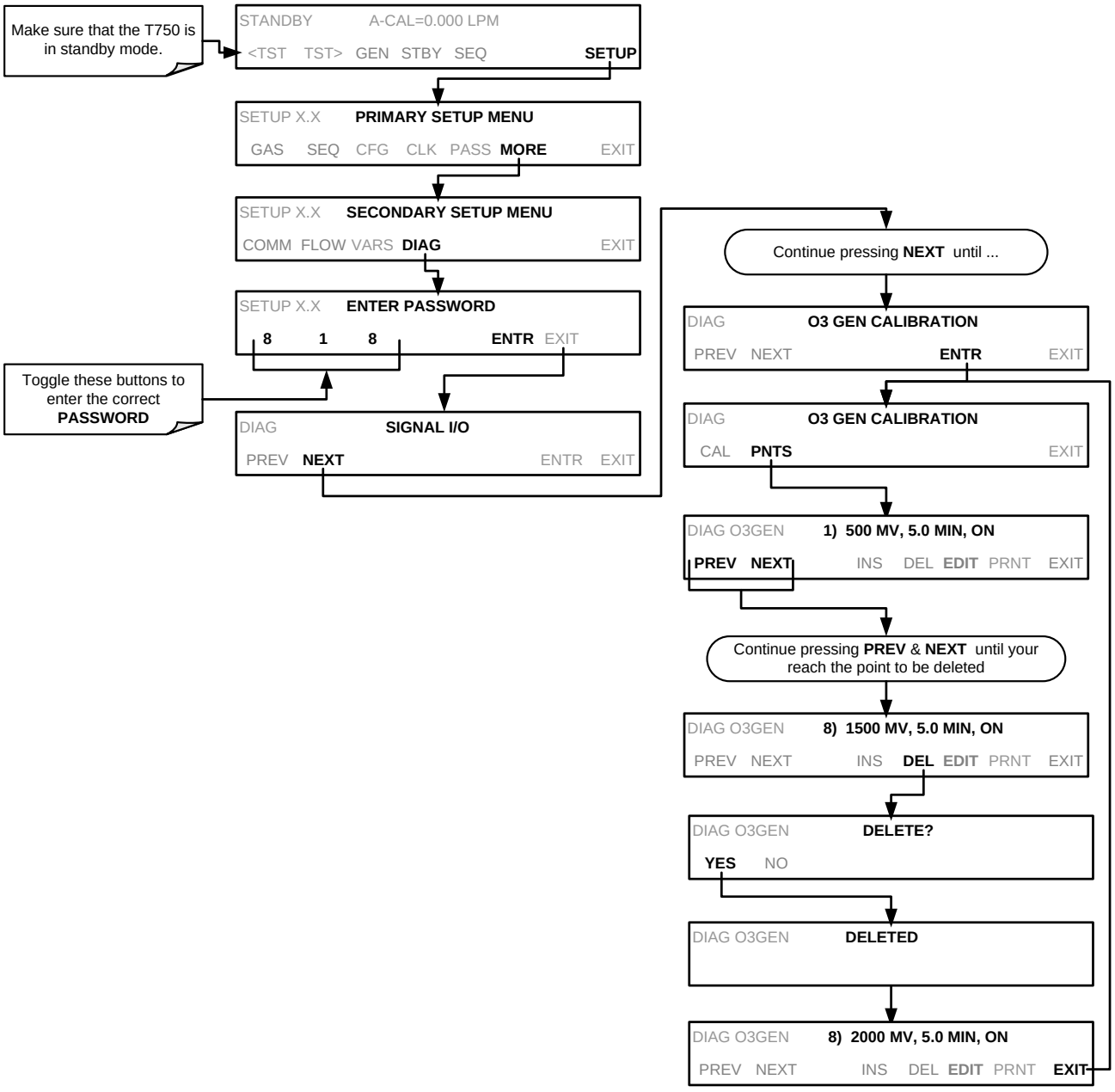
7.4.2.2. **Adding or Editing O_3 Generator Calibration Points**

To add a calibration point to the table or edit an existing point, press:



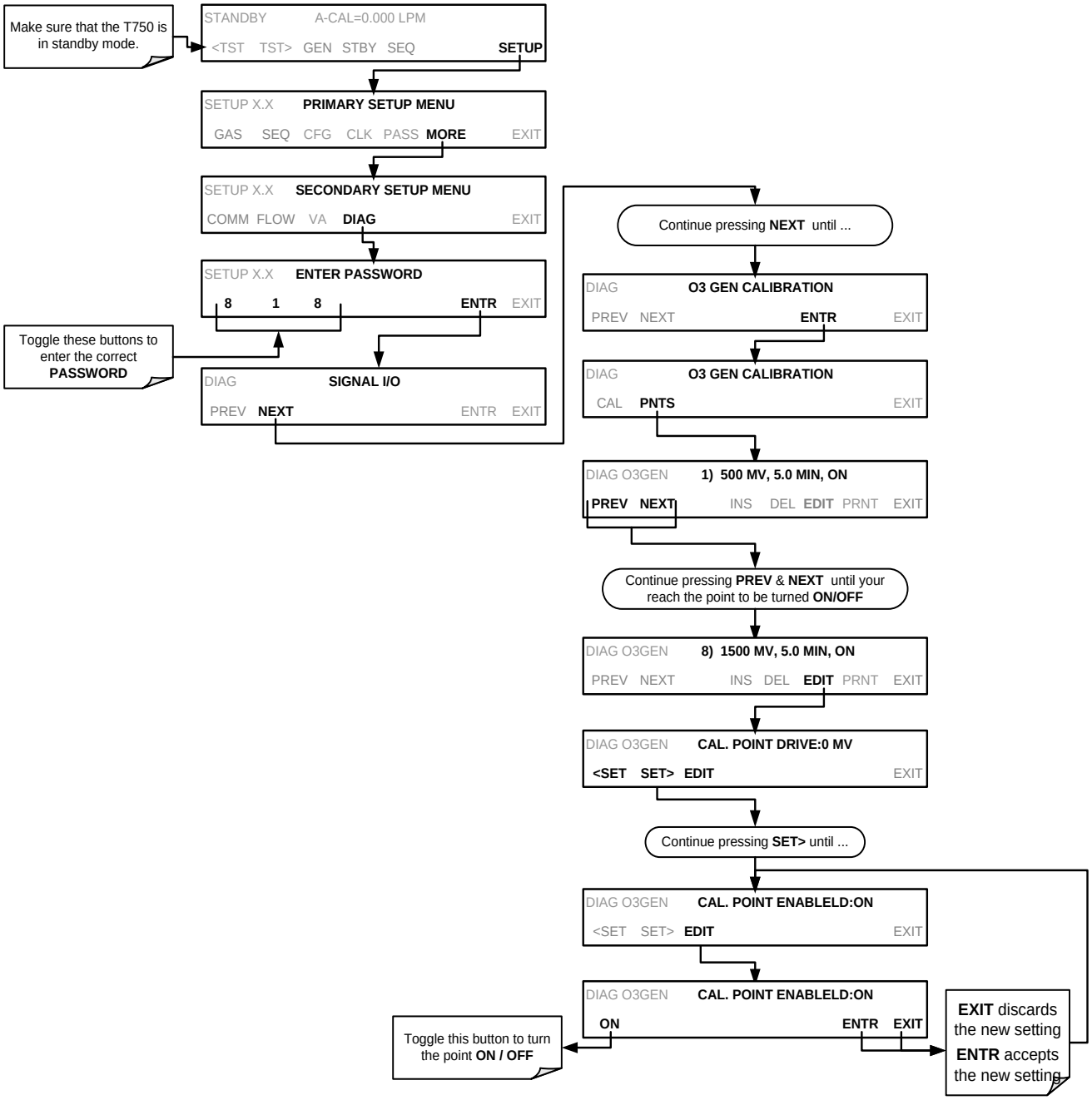
7.4.2.3. **Deleting O_3 Generator Calibration Points**

To delete an existing calibration point, press:



7.4.2.4. **Turning O_3 Generator Calibration Points ON / OFF**

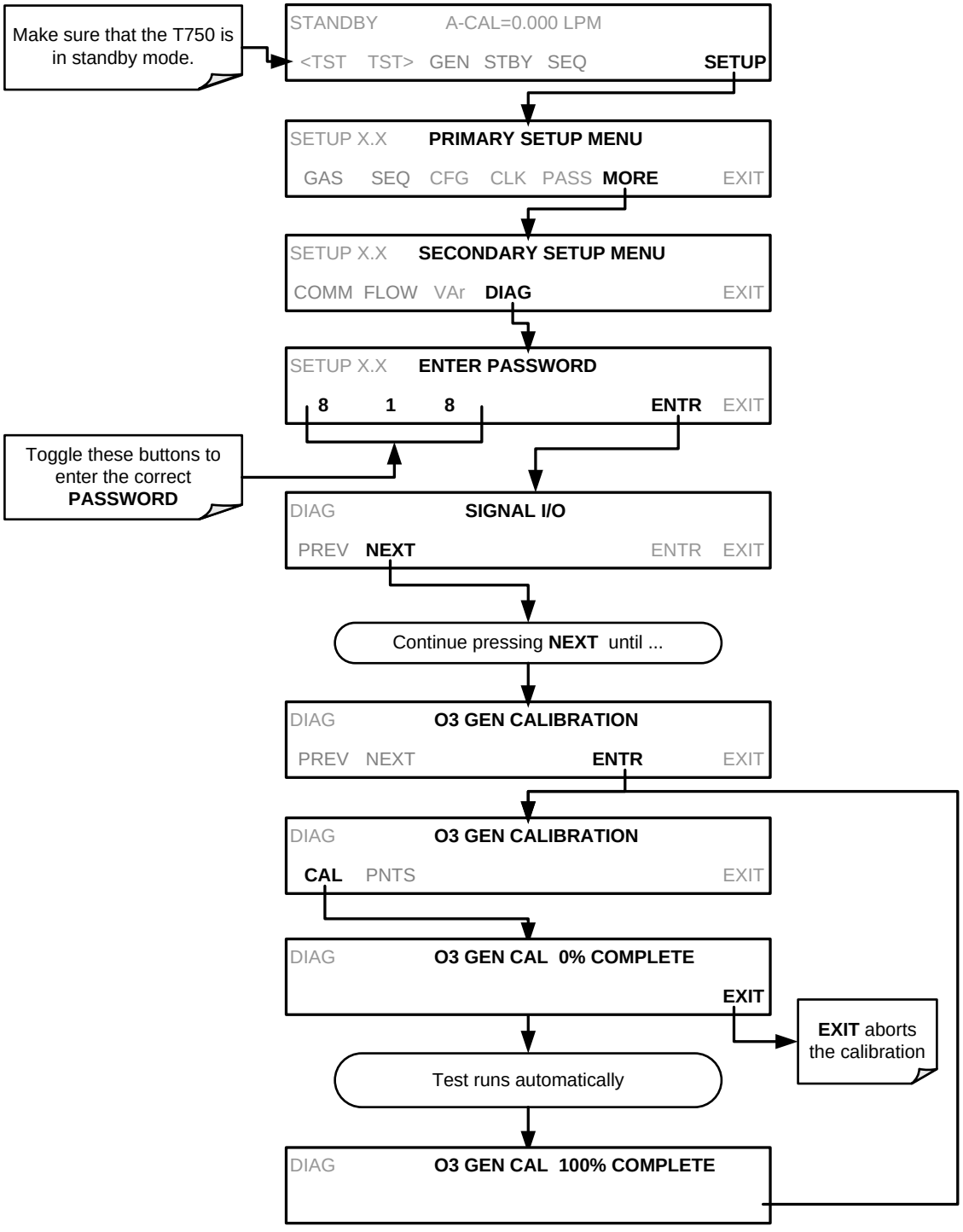
To enable or disable an existing calibration point, press:



7.4.2.5. **Performing an Automatic Calibration of the Optional O_3 Generator**

Note **This procedure requires that the T750 calibrator have an optional photometer installed.**

To run the automatic O_3 generator calibration program, press:



7.5. T750 GAS PRESSURE SENSOR CALIBRATION

Note **The procedures described in this section require a separate pressure meter/monitor.**

The T750 Portable Calibrator has several sensors that monitor the pressure of the gases flowing through the instrument. The data collected by these sensors are used to compensate the final concentration calculations for changes in atmospheric pressure and is stored in the CPU's memory as various test functions:

Table 7-2: T750 Pressure Sensor Calibration Setup

SENSOR	ASSOCIATED TEST FUNCTION	UNITS	PRESSURE MONITOR MEASUREMENT POINT
Diluent Pressure Sensor	**DIL PRESSURE**	**PSIG**	Insert monitor just before the inlet port of the diluent MFC
Cal Gas Pressure Sensor	**CAL PRESSURE**	**PSIG**	Insert monitor just before the inlet port of the cal gas MFC
O_3 Regulator Pressure Sensor (Optional O_3 Generator)	**REG PRESSURE**	**PSIG**	Insert monitor in line between the regulator and the O_3 gas pressure sensor located on the O_3 generator / photometer pressure / flow sensor PCA
Sample Gas Pressure Sensor (Optional O_3 Photometer)	**PHOTO SPRESS**	**IN-HG-A**	Use monitor to measure ambient atmospheric pressure at the calibrator's location.

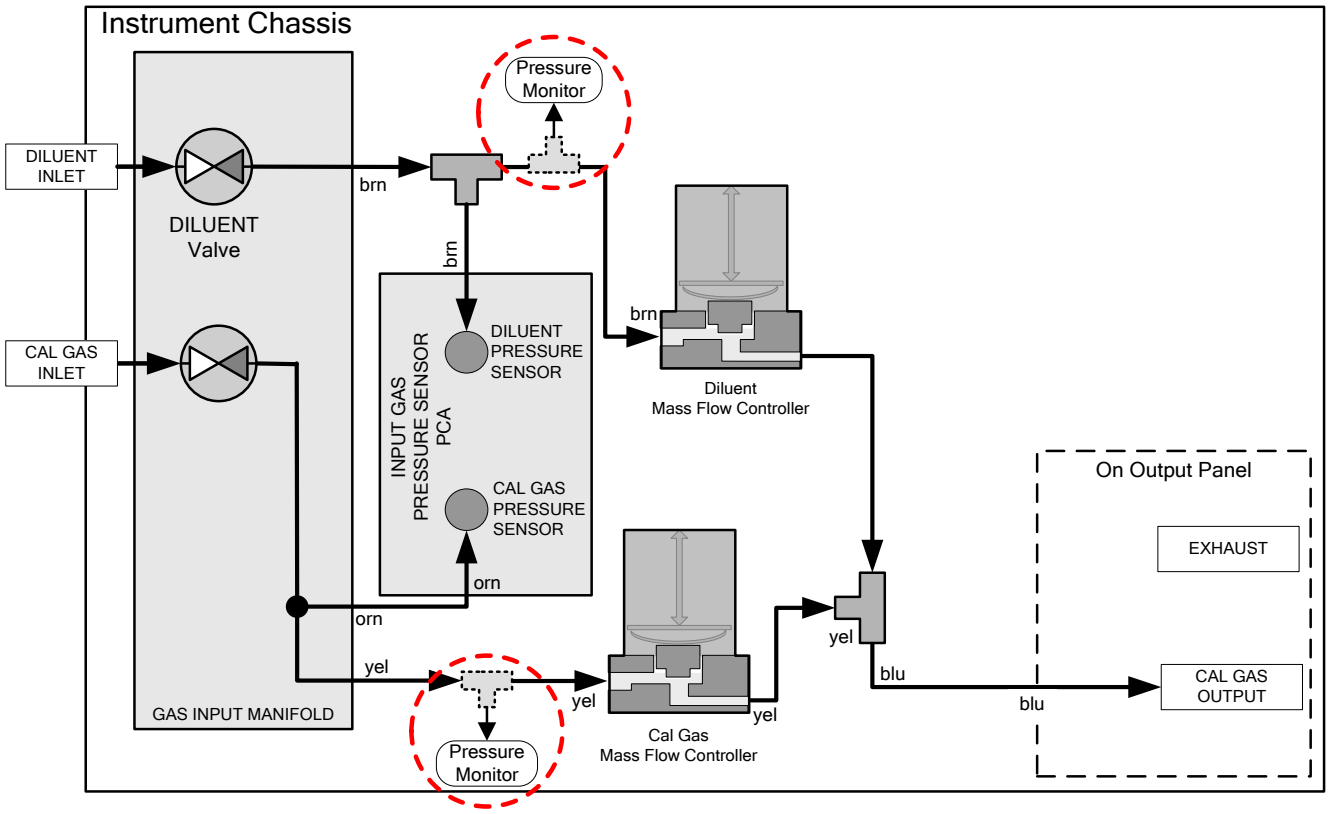


Figure 7-6: Pressure Monitor Points – T750 – Basic Unit

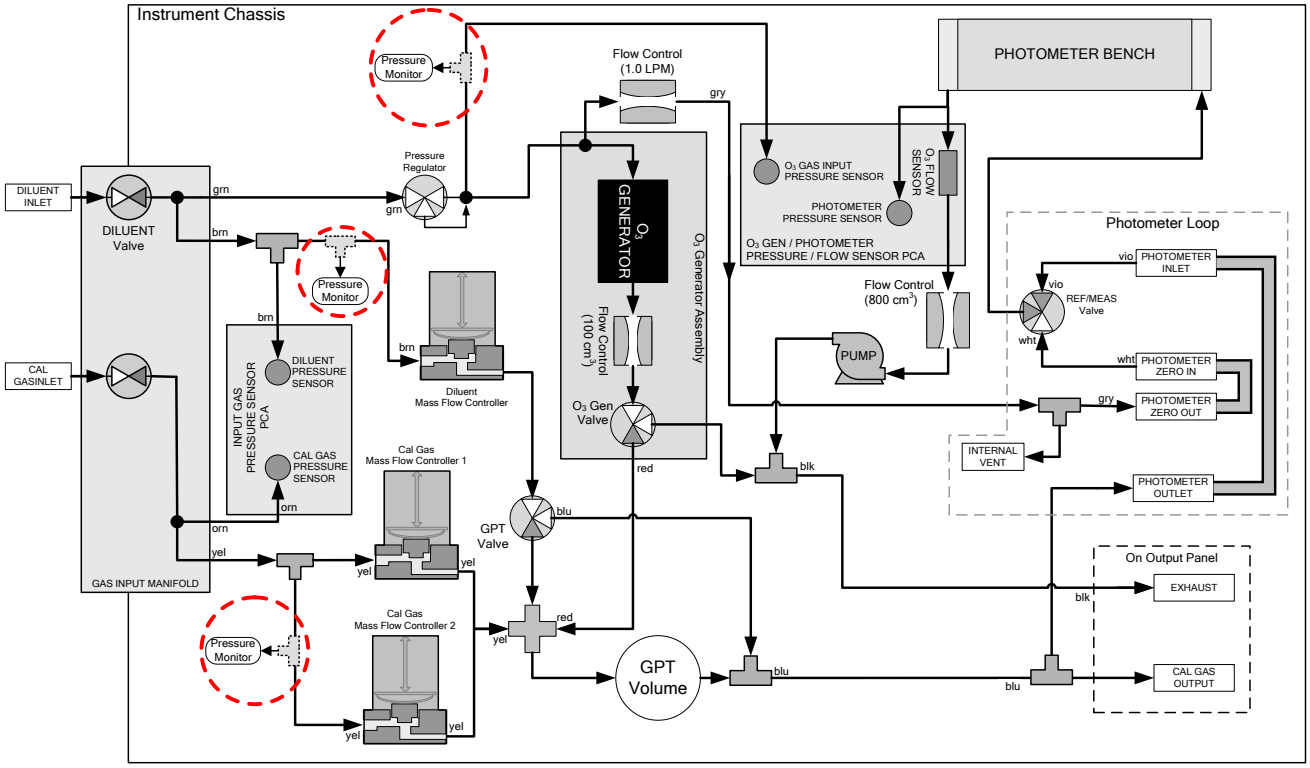
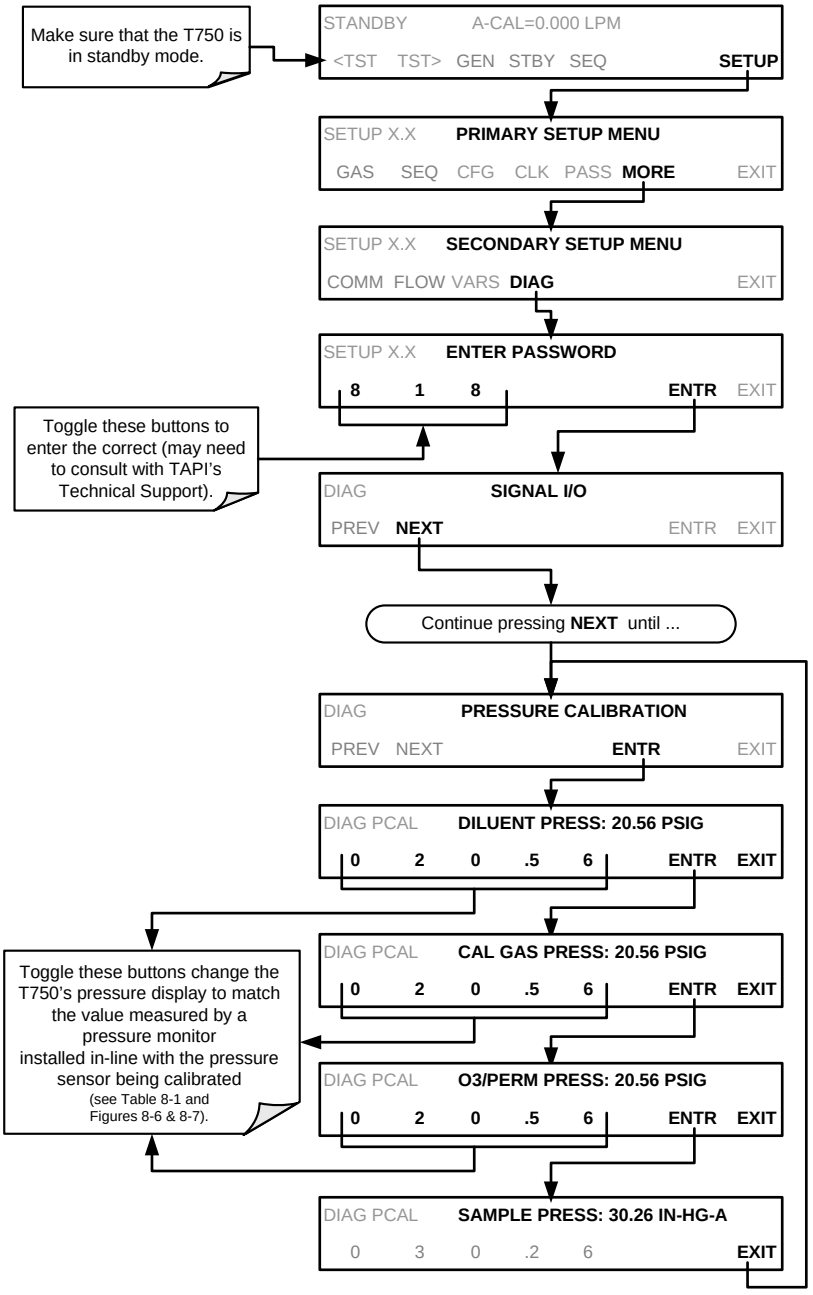


Figure 7-7: Pressure Monitor Points – T750 with O_3 Options and Multiple Cal MFCs Installed

7.5.1.1. **Calibrating the Diluent, Cal Gas Optional O_3 Generator Pressure Sensors**

1. Turn off the calibrator and open its panels.
2. For the sensor being calibrated, insert a “T” pneumatic connector at the location described in Table 7-2 and shown in Figure 7-6 and Figure 7-7.
3. Turn on the calibrator and perform the following steps:



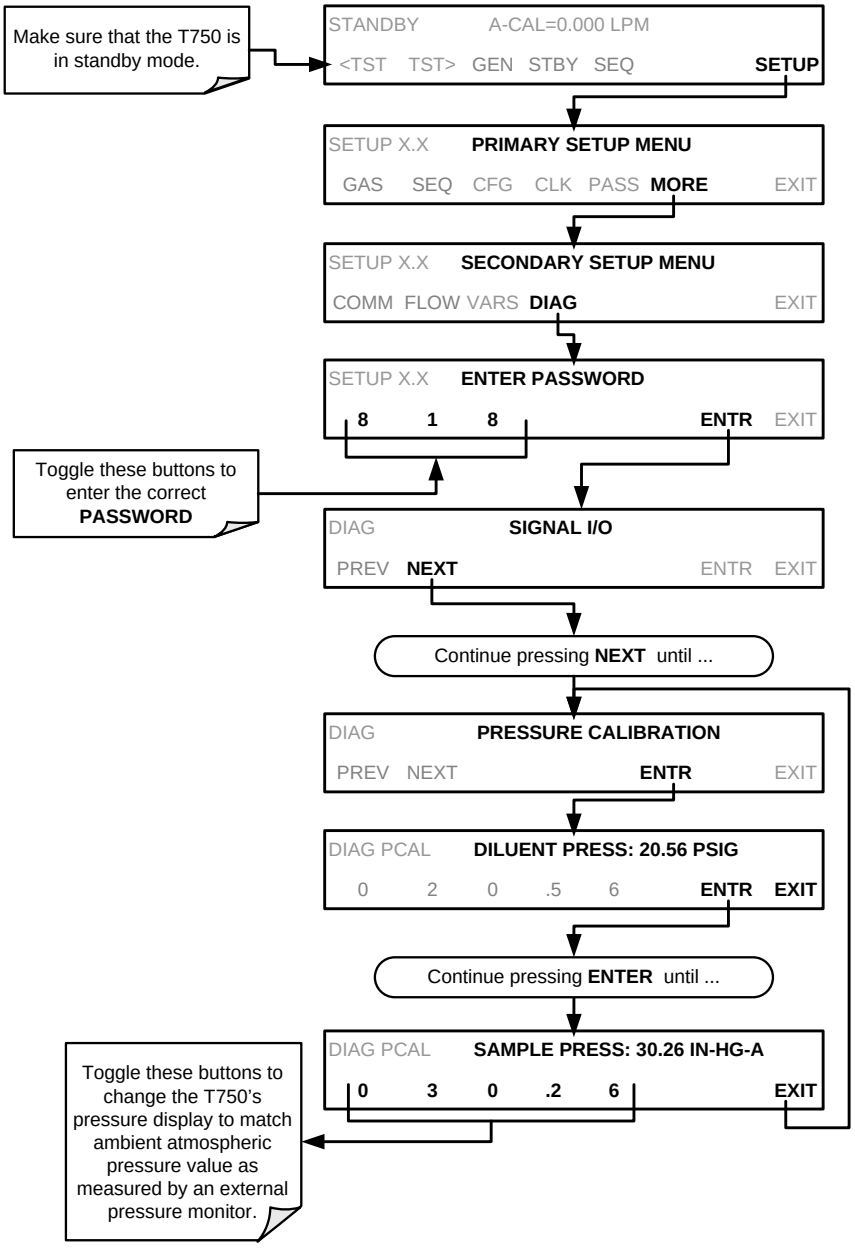
4. Turn OFF the T750.
5. Remove the pressure monitor.
6. Restore the pneumatic lines to their proper connections.
7. Close the calibrator’s panels.

7.5.1.2. **Calibrating the Optional O_3 Photometer Sample Gas Pressure Sensors**

Note

This calibration must be performed when the pressure of the photometer sample gas is equal to ambient atmospheric pressure.

1. Turn off the calibrator and open the panels.
2. Disconnect power to the photometer's internal pump.
3. Measure the ambient atmospheric pressure of T750's location in In-Hg-A.
4. Turn on the calibrator and perform the following steps:



5. Turn OFF the T750.
6. Reconnect the internal pump.
7. Close the calibrator's panels.

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8. MAINTENANCE

Predictive diagnostic functions including failure warnings and alarms built into the calibrator's firmware allow the user to determine when repairs are necessary without performing painstaking preventative maintenance procedures.

For the most part, the T750 calibrator is maintenance free; there are, however, a minimal number of simple procedures that when performed regularly will ensure that the T750 photometer continues to operate accurately and reliably over its lifetime.

Service and troubleshooting are covered in Section 9 of this manual.

8.1. MAINTENANCE SCHEDULE

Table 8-1 shows a typical maintenance schedule for the T750. Please note that in certain environments (i.e. dusty, very high ambient pollutant levels) some maintenance procedures may need to be performed more often than shown.

Note **If the instrument has the optional O_3 photometer installed, a Span and Zero Calibration Check must be performed on the photometer following some of the maintenance procedure listed below. See Section 7.3 for instructions on performing checks.**

WARNING - RISK OF ELECTRICAL SHOCK

DISCONNECT POWER BEFORE PERFORMING ANY OF THE FOLLOWING OPERATIONS THAT REQUIRE ENTRY INTO THE INTERIOR OF THE CALIBRATOR.

CAUTION

THE OPERATIONS OUTLINED IN THIS SECTION ARE TO BE PERFORMED BY QUALIFIED MAINTENANCE PERSONNEL ONLY.

CAUTION

NEVER REMOVE THE INSTRUMENT FROM ITS CASE WITHOUT EXPRESS INSTRUCTION FROM TELEDYNE API TECHNICAL SUPPORT

Table 8-1: T750 Maintenance Schedule

Item	Action	Frequency	Cal Check Req'd.[1]	Manual Section	Date Performed									
Verify Test Functions	Record and analyze	Weekly or after any Maintenance or Repair	No											
Pump Diaphragm[1]	**No Replacement Required. Under Normal Circumstances this Pump Will Last the Lifetime of the Instrument.**													
Absorption Tube[1]	Inspect - - - Clean	As Needed	Yes after cleaning	8.2.2	**Cleaning of the Photometer Absorption Tube Should Not Be Required as long as ONLY CLEAN, DRY, PARTICULATE FREE Zero Air (Diluent Gas) is used with the T750 Calibrator**									
Perform Flow Check	Verify Flow of MFCs	Annually or any time the T750's internal DAC is recalibrated	No	7.1 & 7.2										
Perform Leak Check	Verify Leak Tight	Annually or after any Maintenance or Repair	Yes	8.2.1										
Pneumatic lines	Examine and clean	As needed	Yes if cleaned	- - -										

[1] Only applies to T750 Calibrators with O_3 photometer options installed.

8.2. MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the T750 calibrator.

8.2.1. AUTO LEAK CHECK

8.2.1.1. Equipment Required

- One 1/4” pneumatic cap for CAL GAS OUTPUT fitting on T750 basic configuration,

Or, for T750 models with the O_3 generator with photometer option:

- Two (2) 1/4" Pneumatic caps (for EXHAUST and CALGAS OUT ports)
- One (1) 1/8” Pneumatic Cap (for internal vent)

8.2.1.2. Two (2) pneumatic tube clamps, KIT000322Setup for Auto Leak Check

To perform a leak check, first set up the T750 as follows (see Figure 8-3 and Figure 8-4):

For illustrations of pneumatic flow in the basic model and with the optional photometer, respectively):

1. Power off the instrument.
2. Use the 1/4" caps to cover the EXHAUST and CALGAS OUT ports on the communications and output panel (Figure 3-5).

Note **If a bottle of source gas is connected to the CYL IN port, close the gas outlet of the bottle first, and then disconnect the gas line from the CYL IN port.**

3. Connect a gas line from the zero air gas source to the DILUENT IN port on the control/display and inputs panel (Figure 3-1).
4. Open the calibrator’s panels.

For instruments with basic configuration, skip the next two steps.

5. On instruments with the optional O_3 photometer installed, clamp off the input to the photometer flow sensor and clamp off the pump output (refer to Figure 8-1:

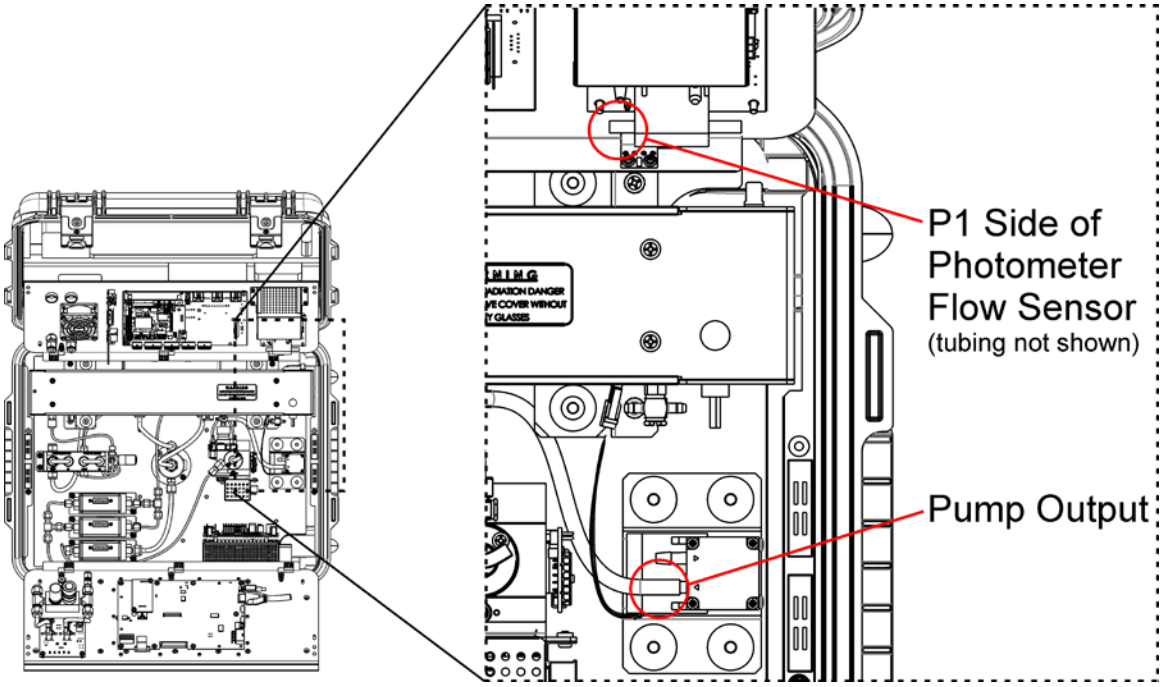


Figure 8-1: Clamping the Photometer Sensor Input and Pump Output

6. Use the 1/8” cap to securely cover the outlet of the internal vent (Figure 8-2).

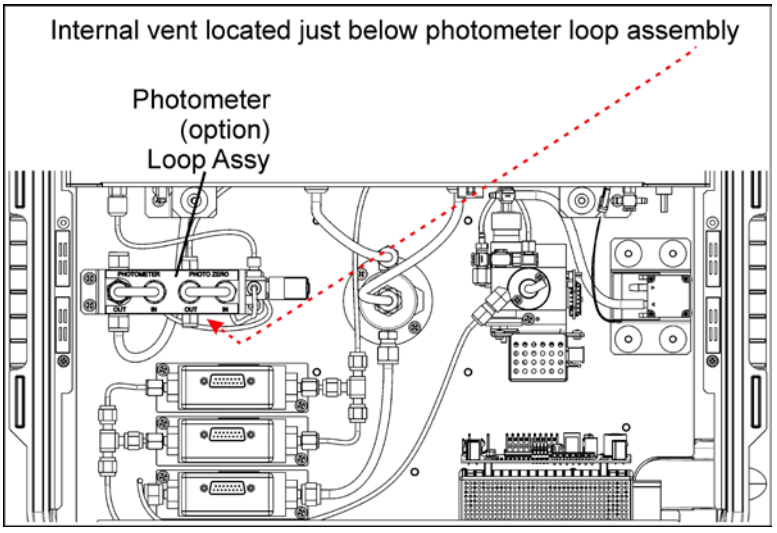


Figure 8-2: Internal Vent Location

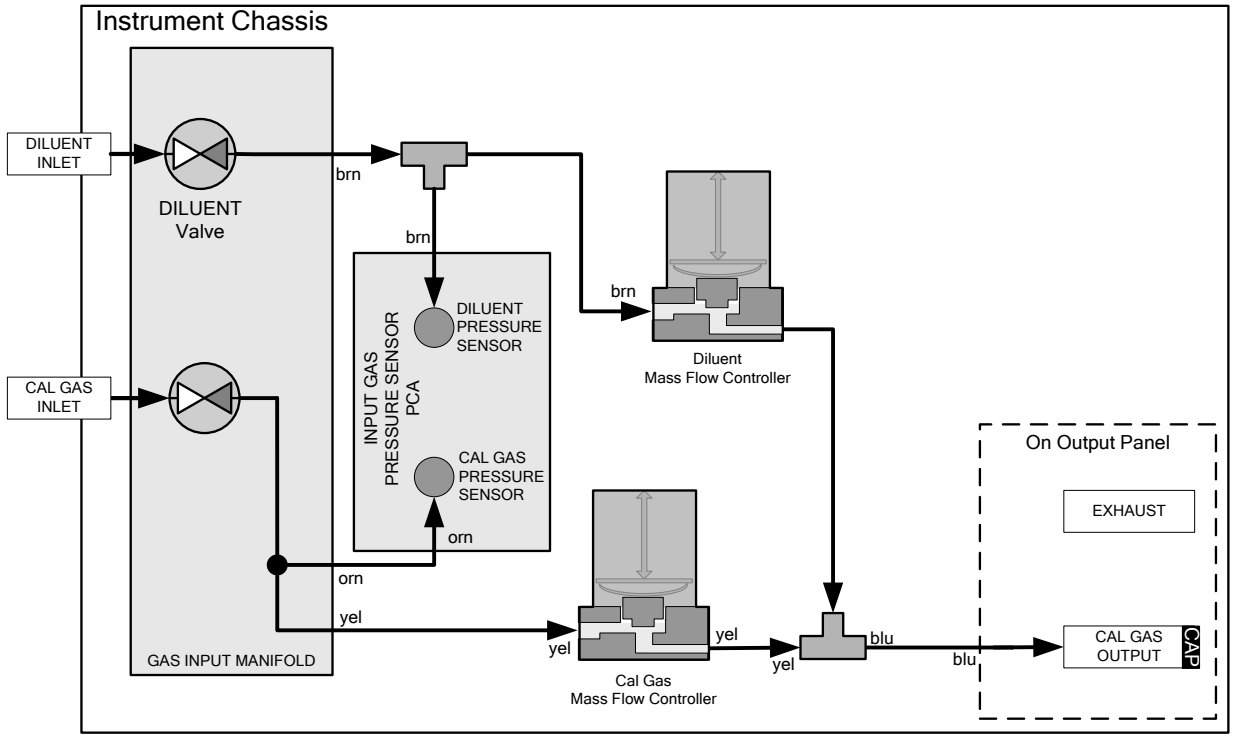


Figure 8-3: Gas Flow for Auto-Leak Check Procedure of Base Model T750

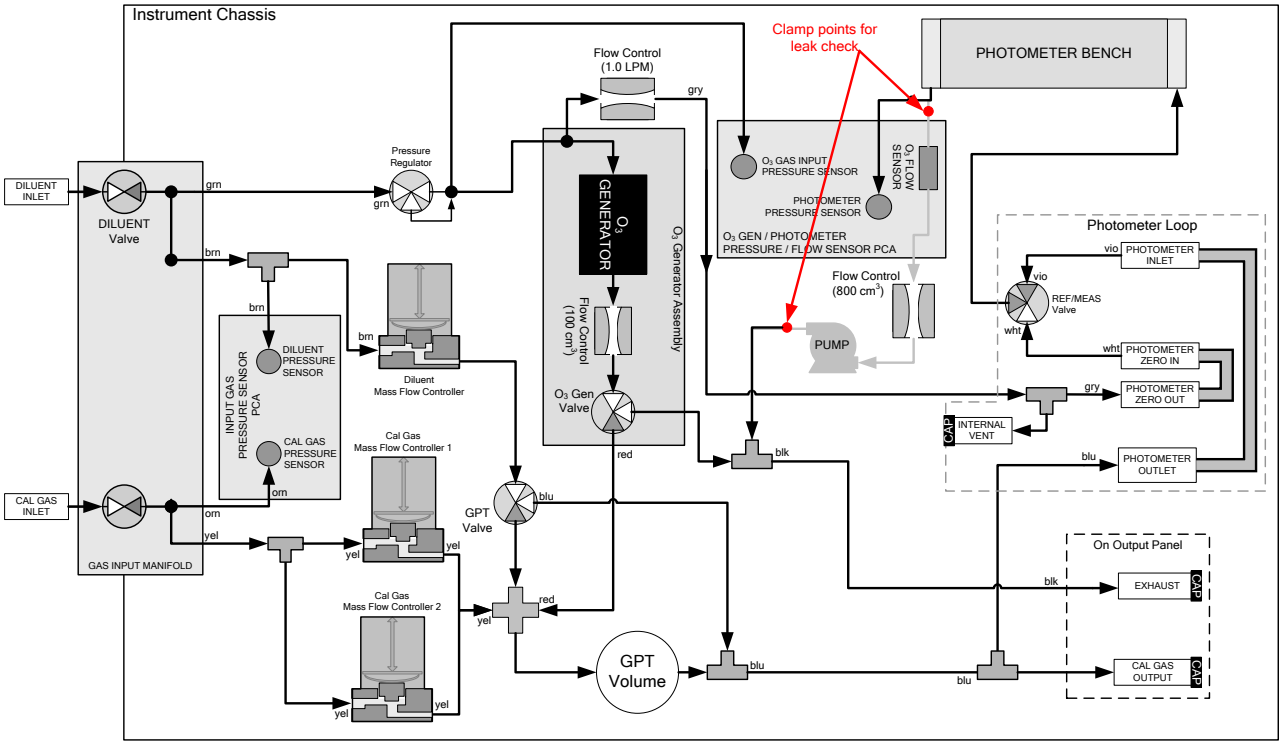
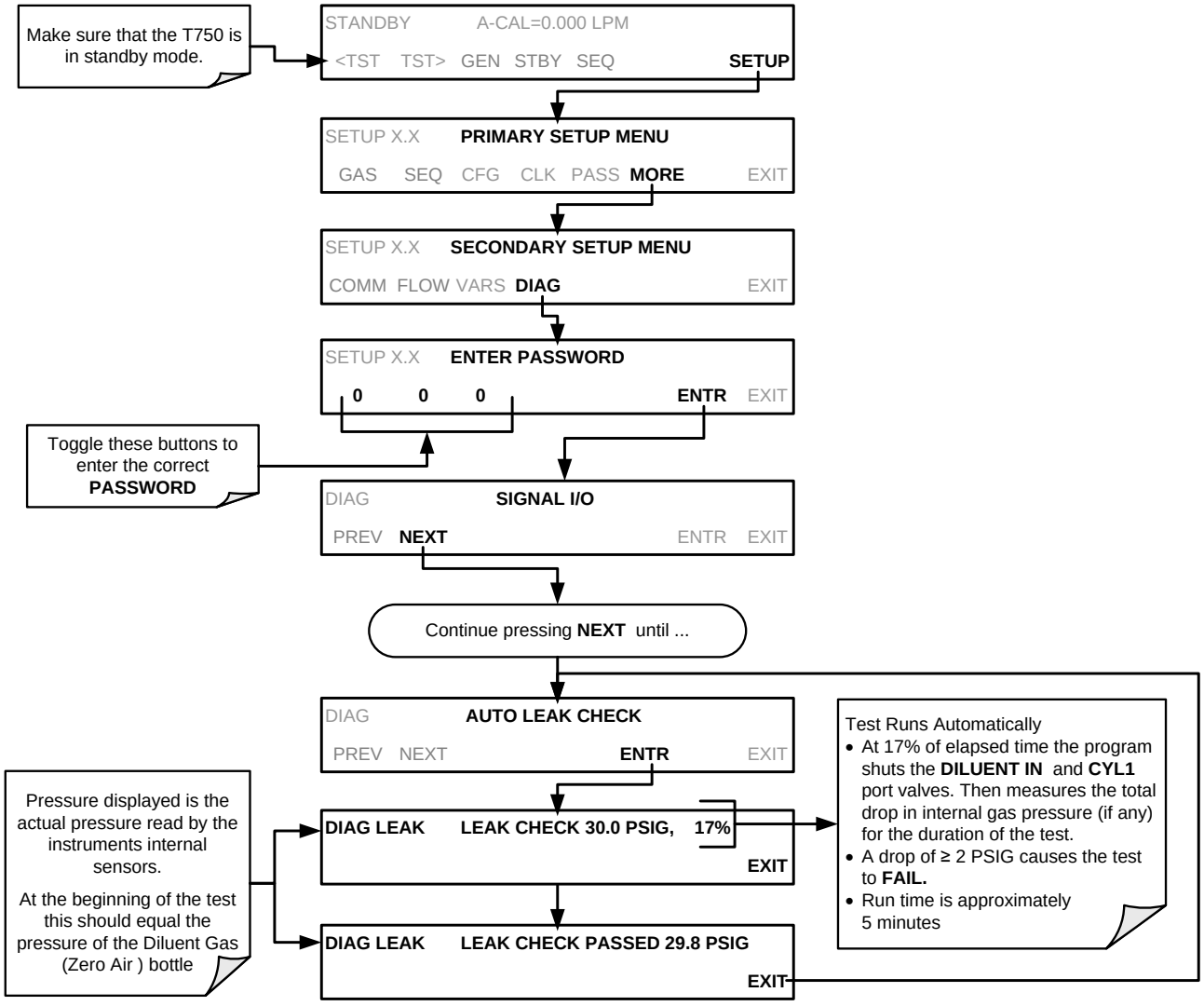


Figure 8-4: Gas Flow for Auto-Leak Check Procedure of T750 with Optional Photometer

7. Proceed to the next step in Section 8.2.1.3, Running the Auto Leak Check Procedure.

8.2.1.3. **Running the Auto Leak Check Procedure**

To run an **AUTO LEAK CHECK**, after the preceding setup procedure, power on the instrument, and on the control/display screen press:



8.2.1.4. **Returning the T750 to Service after Performing an Auto Leak Check**

1. Remove all of the caps from the EXHAUST, the CALGAS OUT, and the internal vent.
2. On instruments with an optional O_3 photometer, remove the clamps that were installed in Step 5 of the setup procedures in Section 8.2.1.2.
3. Remove the tee from the DILUENT IN and CYL 1.
4. Reconnect the zero air source to DILUENT IN.
5. Reconnect the cal gas bottle to CYL 1 and open the bottle's outlet port.
6. Close the calibrator's panels.
7. The calibrator is now ready to be used.

8.2.2. CLEANING OR REPLACING THE ABSORPTION TUBE

Note

Although this procedure should never be needed as long as the user is careful to supply the photometer with clean, dry and particulate free zero air only, it is included here for those rare occasions when cleaning or replacing the absorption tube may be required.

1. Remove the center cover from the optical bench.
2. Unclip the sample thermistor from the tube.
3. Loosen the two screws on the round tube retainers at either end of the tube.
4. Using both hands, carefully rotate the tube to free it.
5. Slide the tube towards the lamp housing.
   - The front of the tube can now be slid past the detector block and out of the instrument.

CAUTION

DO NOT CAUSE THE TUBE TO BIND AGAINST THE METAL HOUSINGS. THE TUBE MAY BREAK AND CAUSE SERIOUS INJURY.

6. Clean the tube by rinsing with de-ionized water.
7. Air-dry the tube.
8. Check the cleaning job by looking down the bore of the tube.
   - It should be free from dirt and lint.
9. Inspect the o-rings that seal the ends of the optical tube (these o-rings may stay seated in the manifolds when the tube is removed).
10. If there is any noticeable damage to these o-rings, they should be replaced.
11. Re-assemble the tube into the lamp housing and perform an Auto Leak Check on the instrument.

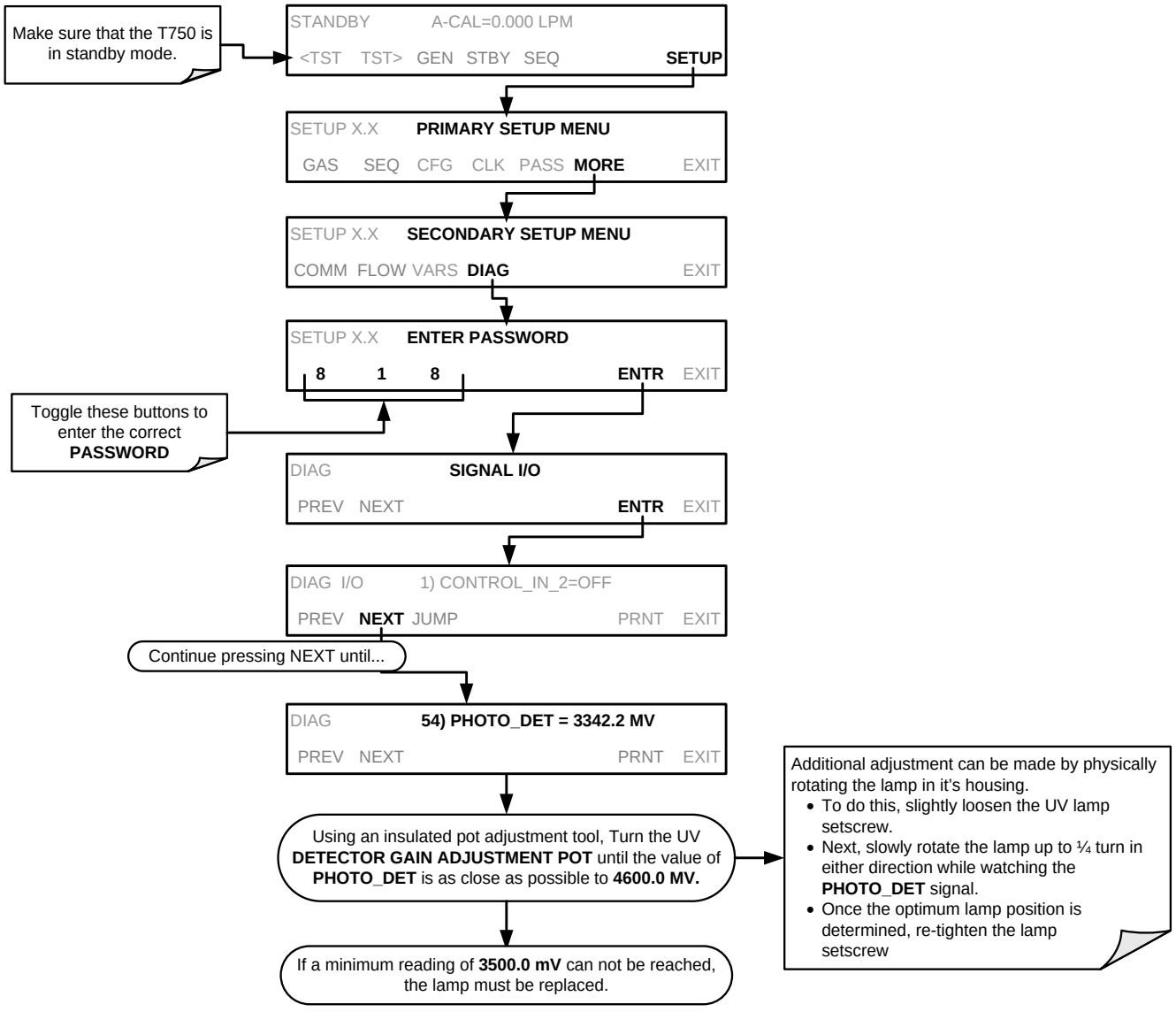
Note

It is important for proper optical alignment that the tube be pushed all the way towards the front of the optical bench when it is reassembled prior to gently retightening the tube retainer screws. This will ensure that the tube is assembled with the forward end against the stop inside the detector manifold.

8.2.3. UV SOURCE LAMP ADJUSTMENT

This procedure provides the steps to adjust the UV source lamp in the optical bench assembly. Follow this procedure whenever the **PHOTO REFERENCE** test function value drops below 3000 mV.

1. Ensure that the calibrator is warmed-up and has been running for at least 30 minutes before proceeding.
2. Open the calibrator's panels.
3. Locate the optional Photometer (see Figure 3-4).
4. Locate the UV detector gain adjust pot on the photometer assembly (see Figure 8-5).
5. Perform the following procedure:



6. Close the calibrator's panels.

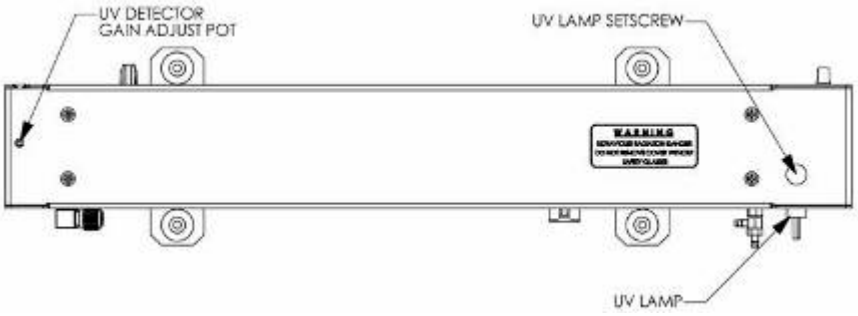


Figure 8-5: Photometer Assembly – Lamp Adjustment / Installation

8.2.4. UV SOURCE LAMP REPLACEMENT

This procedure details the steps for UV source lamp replacement in the optical bench assembly, which should be done whenever the lamp can no longer be adjusted as described in Section 8.2.3.

1. Turn the calibrator off.
2. Open the calibrator's panels.
3. Locate the Optical Bench Assembly (see Figure 3-4).
4. Locate the UV lamp at the front of the optical bench assembly (see Figure 8-5).
5. Unplug the lamp cable from the power supply connector on the side of the optical bench.
6. Slightly loosen (do not remove) the UV lamp setscrew and pull the lamp from its housing.
7. Install the new lamp in the housing, pushing it all the way in. Leave the UV lamp setscrew loose for now.
8. Turn the calibrator back on and allow it to warm up for at least 30 minutes.
9. Turn the UV detector gain adjustment pot (See Figure 8-5) clockwise to its minimum value. The pot may click softly when the limit is reached.
10. Perform the UV Lamp Adjustment procedure described in Section 8.2.3, with the following exceptions:
    a) Slowly rotate the lamp in its housing (up to ¼ turn in either direction) until a **MINIMUM** value is observed.
        - Ensure the lamp is pushed all the way into the housing while performing this rotation.
        - If the PHOTO_DET will not drop below 5000 mV while performing this rotation, contact Teledyne API's Technical Support for assistance.

b) Once the lamp position corresponds to a minimum observed value for **PHOTO_DET**, tighten the lamp setscrew at the approximate minimum value observed.

c) Adjust PHOTO_DET within the range of 4400 – 4600 mV.

11. Close the calibrator's panels.

CAUTION

The UV lamp contains mercury (Hg), which is considered hazardous waste. The lamp should be disposed of in accordance with local regulations regarding waste containing mercury.

8.2.5. OZONE GENERATOR UV LAMP ADJUSTMENT OR REPLACEMENT

This procedure details the steps for replacement and initial adjustment of the ozone generator lamp. If you are adjusting an existing lamp, skip to Step 8.

1. Turn off the calibrator.
2. Open the calibrator's panels.
3. Locate the O_3 generator (see Figure 3-4).

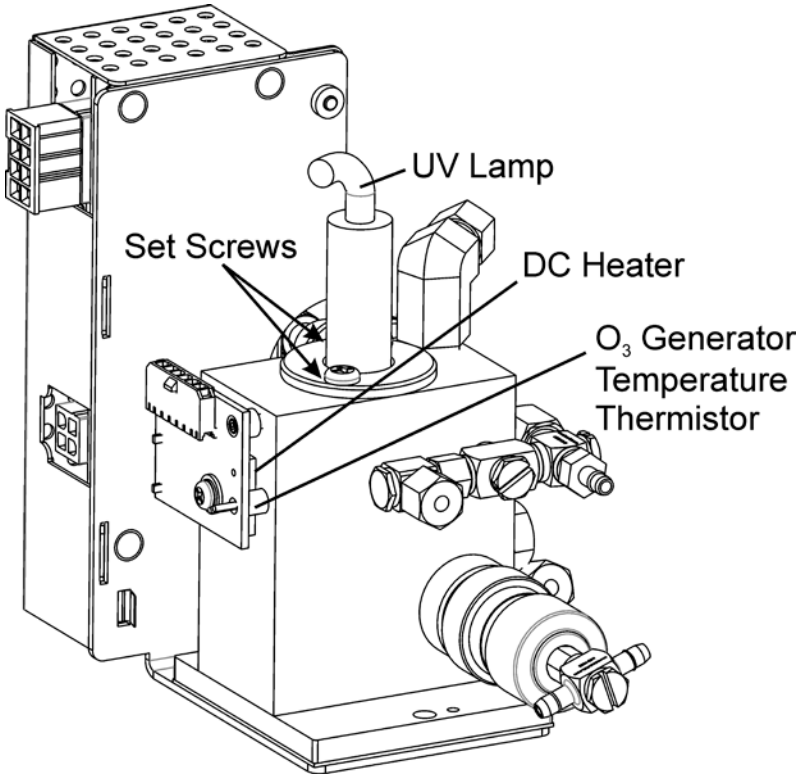


Figure 8-6: O_3 Generator Temperature Thermistor and DC Heater Locations

4. Remove the two setscrews on the top of the O_3 generator and gently pull out the old lamp.
5. Inspect the o-ring beneath the nut and replace if damaged.
6. Install the new lamp in O_3 generator housing.
   - The lamp should be able to be rotated in the assembly by grasping the lamp cable.
   - Ensure that the lamp is fully seated in the O_3 housing.
7. Tighten the two setscrews.
8. Turn on calibrator and allow it to stabilize for at least 30 minutes.
9. Perform an auto-leak check (see Section 8.2.1).
10. Perform an Ozone Generator calibration (see Section 7.4).

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9. TROUBLESHOOTING AND SERVICE

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

ATTENTION

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 instrument open and running.
- Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the calibrator.
- Do not drop tools into the calibrator or leave those after your procedures.
- Do not shorten or touch electric connections with metallic tools while operating inside the calibrator.
- Use common sense when operating inside a running calibrator.

9.1. GENERAL TROUBLESHOOTING

The T750 Portable Calibrator has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its operating parameters without disturbing monitoring operations.

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

1. Note any warning messages and take corrective action as necessary.
2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs 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 PCA.
- Note that the calibrator's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.

4. Follow the procedures defined in Section 3.5.3 to confirm that the calibrator's vital functions are working (power supplies, CPU, relay PCA, etc.).
   - See Figure 3-4 for general layout of components and sub-assemblies in the calibrator.
   - See the wiring interconnect diagram and interconnect list in Appendix D.

9.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the LCD touchscreen. Table 9-1 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 sub-system (power supply, relay PCA, motherboard) has failed rather than indication of the specific failures referenced by the warnings. In this case, it is recommended that proper operation of power supplies (Section 9.4.3), the relay PCA Section 9.4.7), and the motherboard (Section 9.4.10) be confirmed before addressing the specific warning messages.

The T750 will alert the user that a Warning Message is active by flashing the 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/touchscreen examples provide an illustration of each:

Figure 9-1: CLR (top) and MSG (bottom) Buttons with FAULT LED

The calibrator will also alert the user via the Serial I/O COMM port(s).

To view or clear the various warning messages press:

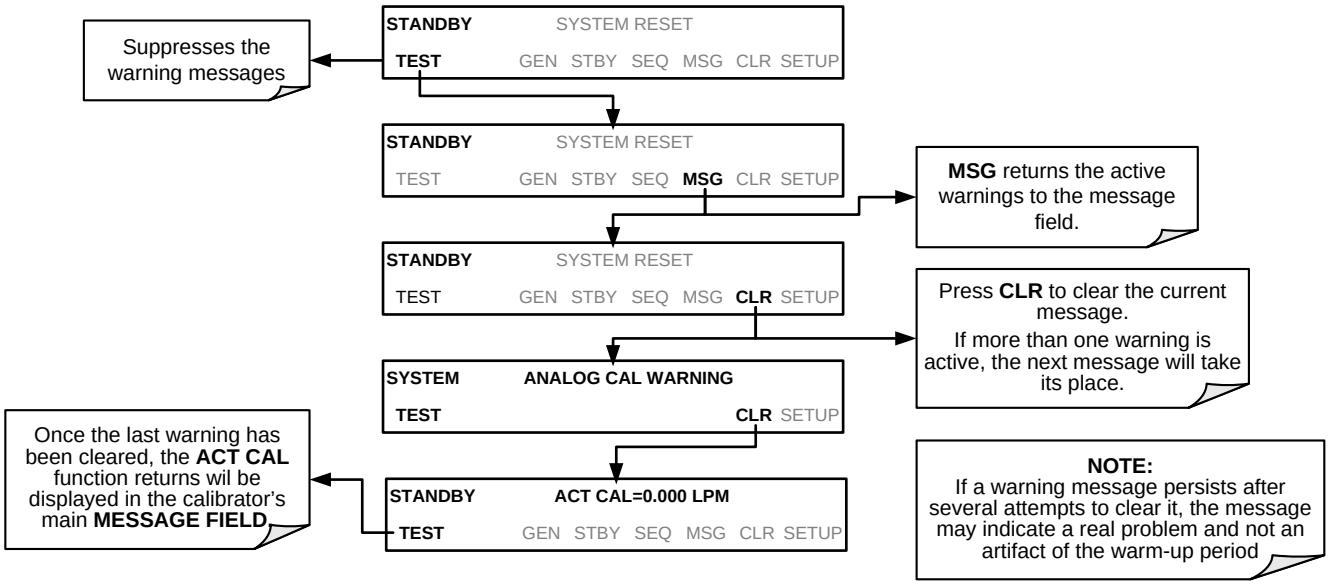


Table 9-1: Warning Messages in LCD Touchscreen Param Field

WARNING	FAULT CONDITION	POSSIBLE CAUSES
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	- Failed Disk-on-Module - User has erased configuration data
DATA INITIALIZED	Data Storage in DAS was erased.	- Failed Disk-on-Module. - User cleared data.
LAMP DRIVER WARN[1, 2]	The CPU is unable to communicate with either the O_3 generator or photometer lamp I^2C driver chip.	- I^2C has failed
MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.	- I^2C has failed - One of the MFCs has failed - Cabling loose or broken between MFC and Motherboard
MFC PRESSURE WARNING	One of the calibrator's mass flow controllers internal gas pressure is <15 PSIG or >36 PSIG	- Zero or source air supply is incorrectly set up or improperly vented. - Leak or blockage exists in the T750's internal pneumatics - Failed CAL GAS or DILUENT pressure sensor
O3 GEN LAMP TEMP WARNING[1]	IZS Ozone Generator Temp is outside of control range of 48°C ± 3°C.	- No IZS option installed, instrument improperly configured - O_3 generator heater - O_3 generator temperature sensor - Relay controlling the O_3 generator heater - Entire Relay PCA - I^2C Bus
O3 PUMP WARNING[1]	The photometer pump failed to turn on within the specified timeout period (default = 30 sec.).	- Failed Pump - Problem with Relay PCA - 12 VDC power supply problem
PHOTO LAMP TEMP WARNING[2]	Photometer lamp temp is <51°C or >61°C.	Possible failure of: - Bench lamp heater - Bench lamp temperature sensor - Relay controlling the bench heater - Entire Relay PCA - I^2C Bus - Hot Lamp
PHOTO LAMP STABILITY WARNING	Value output during the Photometer's reference cycle changes from measurement to measurement more than 25% of the time.	- Faulty UV source lamp - Noisy UV detector - Faulty UV lamp power supply - Faulty ± 15 VDC power supply
PHOTO REFERENCE WARNING[2]	Occurs when Ref is <2500 mVDC or >4950 mVDC.	Possible failure of: - UV Lamp - UV Photo-Detector Preamp
REAR BOARD NOT DET	Mother Board not detected on power up.	- This warning only appears on Serial I/O COMM Port(s) LCD touchscreen will be frozen, blank or will not respond. - Failure of Mother Board
REGULATOR PRESSURE WARNING	Regulator pressure is <15 PSIG or >25 PSIG.	- Zero or source air supply is incorrectly set up or improperly vented. - Incorrectly adjusted O_3 zero air pressure regulator - Leak or blockage exists in the T750's internal pneumatics

WARNING	FAULT CONDITION	POSSIBLE CAUSES
		- Failed O_3 Generator Input pressure sensor
RELAY BOARD WARN	The CPU cannot communicate with the Relay PCA.	- I^2C Bus failure - Failed relay PCA - Loose connectors/wiring
SYSTEM RESET	The computer has rebooted.	- This message occurs at power on. - If it is confirmed that power has not been interrupted - Failed +5 VDC power - Fatal error caused software to restart - Loose connector/wiring

[1] Only applicable for calibrators with the optional the O_3 generator installed.

[2] Only applicable for calibrators with the optional photometer installed.

[3] On instrument with multiple Cal Gas MFCs installed, the **MFC FLOW WARNING** occurs when the flow rate requested is <10% of the range of the lowest rated MFC (i.e. all of the cal gas MFC are turned off).

9.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the test functions viewable from the calibrator's LCD touchscreen can be used to isolate and identify many operational problems when combined with a thorough understanding of the calibrators Theory of Operation (see Section 10).

The acceptable ranges for these test functions are listed in the "Nominal Range" column of the calibrator Final Test and Validation Data Sheet shipped with the instrument. Values outside these acceptable ranges indicate a failure of one or more of the calibrator's subsystems. Functions whose values are still within acceptable ranges but have significantly changed from the measurement recorded on the factory data sheet may also indicate a failure.

A worksheet has been provided in Appendix C to assist in recording the values of these Test Functions.

Table 9-2 contains some of the more common causes for these values to be out of range.

Table 9-2: Test Functions – Indicated Failures

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
O3FLOW[1]	Gas flow problems directly affect the concentration accuracy of the T750's calibration gas mixtures. - Check for Gas Flow problems.
O3GENDRV[1]	Check the O_3 generator heater and temperature sensors. Possible causes of faults are the same as **O3 GEN LAMP TEMP WARNING** from Table 9-1.
O3LAMPTMP[1]	Incorrect Lamp temperature can affect the efficiency and durability of the O_3 generators UV lamp. Possible causes of faults are the same as **O3 GEN LAMP TEMP WARNING** from Table 9-1.
CAL PRES	Affects proper flow rate of Cal gas MFCs. Possible causes of faults are the same as **MFC PRESSURE WARNING** from Table 9-1.
DIL PRES	Affects proper flow rate of Diluent gas MFCs. Possible causes of faults are the same as **MFC PRESSURE WARNING** from Table 9-1.
REG PRES	Same as **REGULATOR PRESSURE WARNING** from Table 9-1.
BOX TMP	If the Box Temperature is out of range, ensure that the: Box Temperature typically runs ~7°C warmer than ambient temperature. - The Exhaust-Fan is running. - Ensure there is sufficient ventilation area to the side and rear of instrument to allow adequate ventilation.
PH MEAS[2] **&** **PH REF**[2]	If the value displayed is too high the UV Source has become brighter. Adjust the variable gain potentiometer on the UV Preamp Board in the optical bench. If the value displayed is too low: - <200mV – Bad UV lamp or UV lamp power supply. - <2500mV – Lamp output has dropped, adjust UV Preamp Board or replace lamp. If the value displayed is constantly changing: - Bad UV lamp. - Defective UV lamp power supply. - Failed I^2C Bus. If the PHOTO REFERENCE value changes by more than 10mV between zero and span gas: - Defective/leaking switching valve.
PH FLW[2]	Gas flow problems directly affect the accuracy of the photometer measurements and therefore the concentration accuracy of cal gas mixtures involving O_3 and GPT mixtures. - Check for Gas Flow problems.
PH LTEMP[2]	Poor photometer temp control can cause instrument noise, stability and drift. Temperatures outside of the specified range or oscillating temperatures are cause for concern. Possible causes of faults are the same as **PHOTO LAMP TEMP WARNING from** Table 9-1.
PH PRES[2]	The pressure of the gas in the photometer's sample chamber is used to calculate the concentration of O_3 in the gas stream. Incorrect sample pressure can cause inaccurate readings. - Check for Gas Flow problems. See Section Table 9-1.

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
PH STEMP[2]	The temperature of the gas in the photometer's sample chamber is used to calculate the concentration of O_3 in the gas stream. Incorrect sample temperature can cause inaccurate readings. Possible causes of faults are: - Bad bench lamp heater - Failed sample temperature sensor - Failed relay controlling the bench heater - Failed Relay PCA - I^2C Bus malfunction - Hot Lamp
PH SLOPE[2]	Values outside range indicate: ▪ Contamination of the Zero Air or Span Gas supply. ▪ Instrument is miss-calibrated. ▪ Blocked Gas Flow. ▪ Faulty Sample Pressure Sensor or circuitry. ▪ Bad/incorrect Span Gas concentration.
PH OFFST[2]	Values outside range indicate: ▪ Contamination of the Zero Air supply.
TIME	Time of Day clock is too fast or slow. ▪ To adjust see Section 4.5. ▪ Battery in clock chip on CPU board may be dead.
[1] Only appears when the optional O_3 generator is installed. [2] Only appears when the optional O_3 photometer is installed	

9.1.3. **USING THE DIAGNOSTIC SIGNAL I/O FUNCTION**

The Signal I/O parameters found under the DIAG Menu combined with a thorough understanding of the instrument's Theory of Operation (found in Section 10) are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the calibrator's critical inputs and outputs.
- Many of the components and functions that are normally under algorithmic control of the CPU can be manually exercised.
- The technician can directly control the signal level Analog and Digital Output signals.

This allows the technician to observe systematically the effect of directly controlling these signals on the operation of the calibrator. Figure 9-2 is 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.

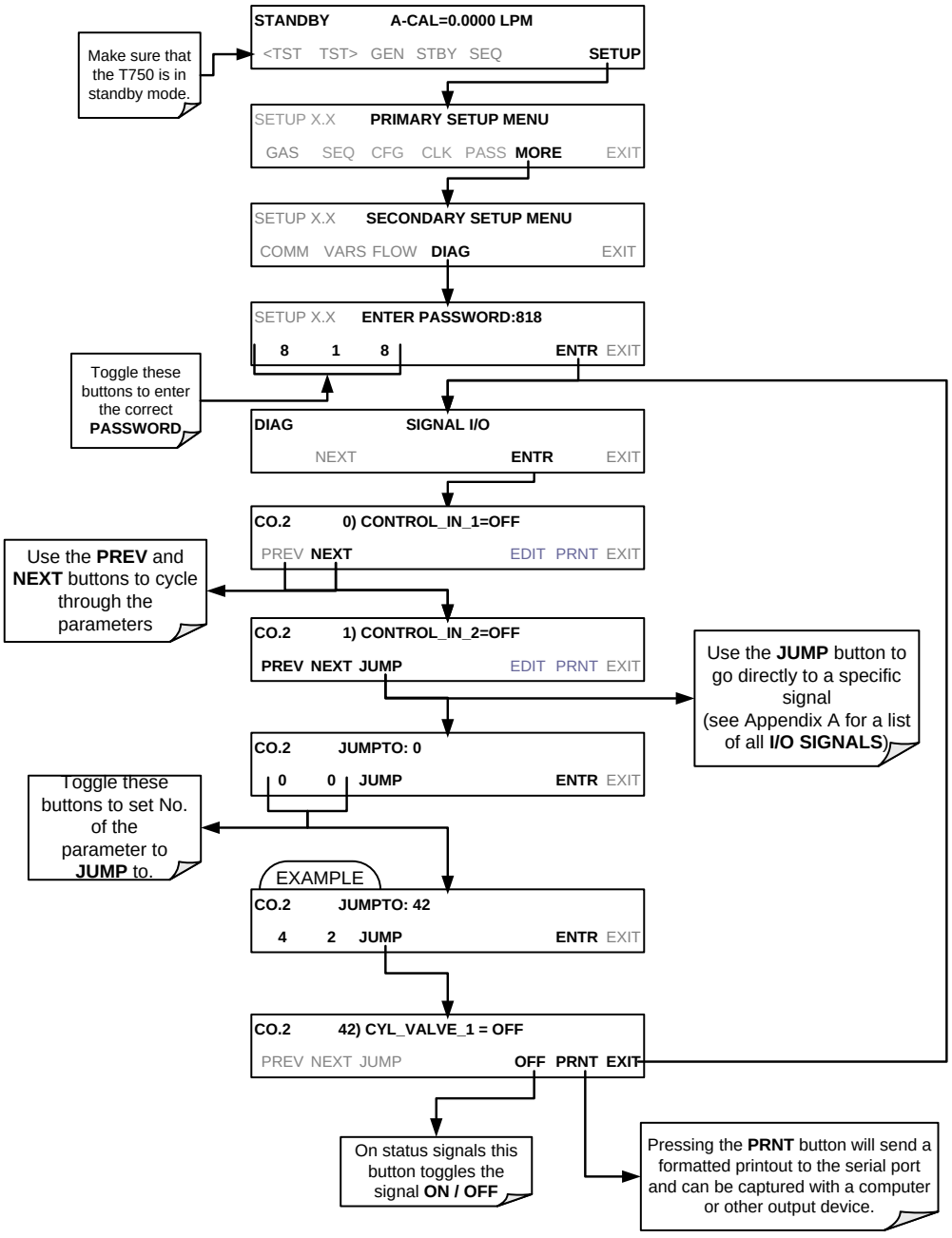


Figure 9-2: Example of Signal I/O Function

9.2. USING THE ANALOG OUTPUT TEST CHANNEL

The signals available for output over the T750's analog output channel can also be used as diagnostic tools. See Section 4.7 for instruction on activating the analog output and selecting a function.

Table 9-3: Test Channel Outputs as Diagnostic Tools

TEST CHANNEL	DESCRIPTION	ZERO	FULL SCALE	CAUSES OF EXTREMELY HIGH / LOW READINGS
NONE	**TEST CHANNEL IS TURNED OFF**			
O3 PHOTO MEAS	The raw output of the photometer during its measure cycle	0 mV	5000 mV*	If the value displayed is: - >5000 mV: The UV source has become brighter; adjust the UV Detector Gain potentiometer. - <100mV – Bad UV lamp or UV lamp power supply. - <2500mV – Lamp output has dropped, adjust UV Preamp Board or replace lamp. If the value displayed is constantly changing: - Bad UV lamp. - Defective UV lamp power supply. - Failed I^2C Bus. If the PHOTO REFERENCE value changes by more than 10mV between zero and span gas: - Defective/leaking M/R switching valve.
O3 PHOTO REF	The raw output of the photometer during its reference cycle	0 mV	5000 mV	
SAMPLE PRESSURE	The pressure of gas in the photometer absorption tube	0 "Hg	40 "Hg-In-A	Check for Gas Flow problems.
SAMPLE FLOW	The gas flow rate through the photometer	0 cm^3/min	1000 cm^3/m	Check for Gas Flow problems.
SAMPLE TEMP	The temperature of gas in the photometer absorption tube	0 C°	70 C°	Possible causes of faults are the same as **PHOTO STEMP** from Table 9-2.
PHOTO LAMP TEMP	The temperature of the photometer UV lamp	0 C°	70 C°	Possible failure of: - Bench lamp heater - Bench lamp temperature sensor - Relay controlling the bench heater - Entire Relay PCA - I^2C Bus - Hot Lamp
O3 LAMP TEMP	The temperature of the O_3 generator's UV lamp	0 mV	5000 mV	Same as **PHOTO LAMP TEMP WARNING from** Table 9-1.
CHASSIS TEMP	The temperature inside the T750's chassis (same as **BOX TEMP**)	0 C°	70 C°	Possible causes of faults are the same as **BOX TEMP** from Table 9-2.
O3 PHOTO CONC	The current concentration of O_3 being measured by the photometer.	- - -		- I^2C Bus malfunction - Gas flow problem through the photometer. - Electronic failure of the photometer subsystems. - Failure or pressure / temperature sensors associated with the photometer. - Bad/incorrect Span Gas concentration. - Contamination of the Zero Air supply. - Malfunction of the O_3 generator. - Internal A/D converter problem.

9.3. USING THE INTERNAL ELECTRONIC STATUS LEDS

Several LEDs are located inside the instrument to assist in determining if the calibrators CPU, I^2C bus and Relay PCA are functioning properly.

9.3.1. CPU STATUS INDICATOR

DS5, a red LED, that is located on upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program loop. After power-up, approximately 30 – 60 seconds, DS5 should flash on and off. If DS5 does not flash then the program files may have become corrupted; contact Technical Support because it may be possible to recover operation of the calibrator. If after 30 – 60 seconds, DS5 is flashing. then the CPU is bad and must be replaced.

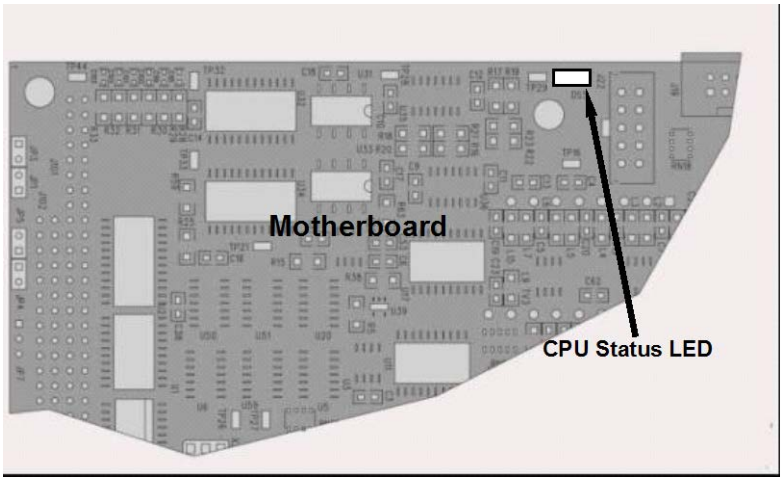


Figure 9-3: CPU Status Indicator

9.3.2. RELAY PCA STATUS LEDS

There are eleven status LEDs located on the Relay PCA (Figure 9-4).

9.3.2.1. I^2C Bus Watchdog Status LEDs

The most important is D1, which indicates the health of the I^2C bus).

Table 9-4: Relay PCA Watchdog LED Failure Indications

LED	Function	Fault Status	Indicated Failure(s)
D1 (Red)	I^2C bus Health (Watchdog Circuit)	Continuously ON or Continuously OFF	Failed/Halted CPU Faulty Mother Board, Valve Driver board or Relay PCA Faulty Connectors/Wiring between Mother Board, Valve Driver board or Relay PCA Failed/Faulty +5 VDC Power Supply (PS1)

If D1 is blinking, then the other LEDs can be used in conjunction with **DIAG** Menu Signal I/O to identify hardware failures of the relays and switches on the Relay.

9.3.2.2. O_3 Option Status LEDs

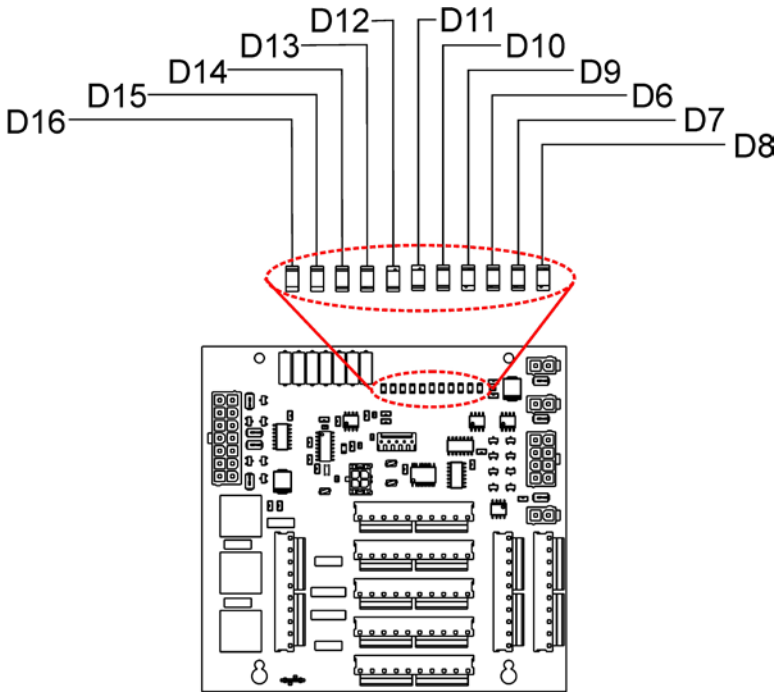


Figure 9-4: Relay PCA Status LEDS Used for Troubleshooting

Table 9-5: Relay PCA Status LED Failure Indications

LED	FUNCTION	SIGNAL I/O PARAMETER		DIAGNOSTIC TECHNIQUE
		ACTIVATED BY	VIEW RESULT	
D7[1]	Photometer Meas/Ref Valve	**PHOTO_REF_VALVE**	N/A	Valve should audibly change states. If not: • Failed Valve • Failed Relay Drive IC on Relay PCA • Failed Relay PCA • Faulty +12 VDC Supply (PS2) • Faulty Connectors/Wiring
D8[2]	O_3 Generator Valve Status	**O3_GEN_VALVE**		
D9[1]	Photometer Pump Status	**O3-PUMP-ON**		
D6[1,2]	GPT Valve Status	**GPT_VALVE**		
D10	Cal Gas Status	**CYL_VALVE**		
D13	Diluent Valve Status	**INPUT_VALVE**		
D15[1]	Photometer Heater Status	**PHOTO_LAMP_HEATER**	**PHOTO_LAMP_TEMP**	Voltage displayed should change. If not: • Failed Heater • Faulty Temperature Sensor • Failed AC Relay • Faulty Connectors/Wiring
D16[2]	O_3 Generator Heater Status	**O3_GEN_HEATER**	**O3_GEN_TEMP**	

[1] Only applies on calibrators with photometer options installed.

[2] Only applies on calibrators with O_3 generator options installed.

D11, D12, and D14 are spare.

9.4. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the T750 calibrator. In most cases, this included a list of possible components or subsystems that might be the source of the problem. This section describes how to check individual components or subsystems to determine whether any is the cause of the problem being investigated.

9.4.1. VERIFY SUBSYSTEM CALIBRATION

A good first step when troubleshooting the operation of the T750 calibrator is to verify that its major subsystems are properly calibrated. These are:

- The mass flow controllers (see Section 7.2).
- Test Channel D → A conversion (see Sections 4.10.1.7, 9.4.10.1, and 10.3.4.1).
- Gas pressure calibration (see Section 7.5).

When optional O_3 components are installed, you should also check:

- Photometer calibration (see Section 7.3).
- O_3 generator calibration (see Section 7.4).

9.4.2. AC MAIN POWER

The T750 calibrator's electronic systems will operate with any of the specified power regimes. As long as the system 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 and light the LCD touchscreen.

- Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

- If they do not, check the circuit breaker built into the ON/OFF.

WARNING

SHOULD THE AC POWER CIRCUIT BREAKER TRIP, INVESTIGATE AND CORRECT THE CONDITION CAUSING THIS SITUATION BEFORE TURNING THE CALIBRATOR BACK ON.

9.4.3. **DC POWER SUPPLY**

If you have determined that the calibrator's AC mains power is working, but the unit is still not operating properly, there may be a problem with one of the instrument's switching power supplies. The supplies can have two faults, namely no DC output, and noisy output.

To assist tracing DC Power Supply problems, the wiring used to connect the various printed circuit assemblies and DC Powered components and the associated test points on the relay PCA follow a standard color-coding scheme as defined in Figure 9-5 and Table 9-6.

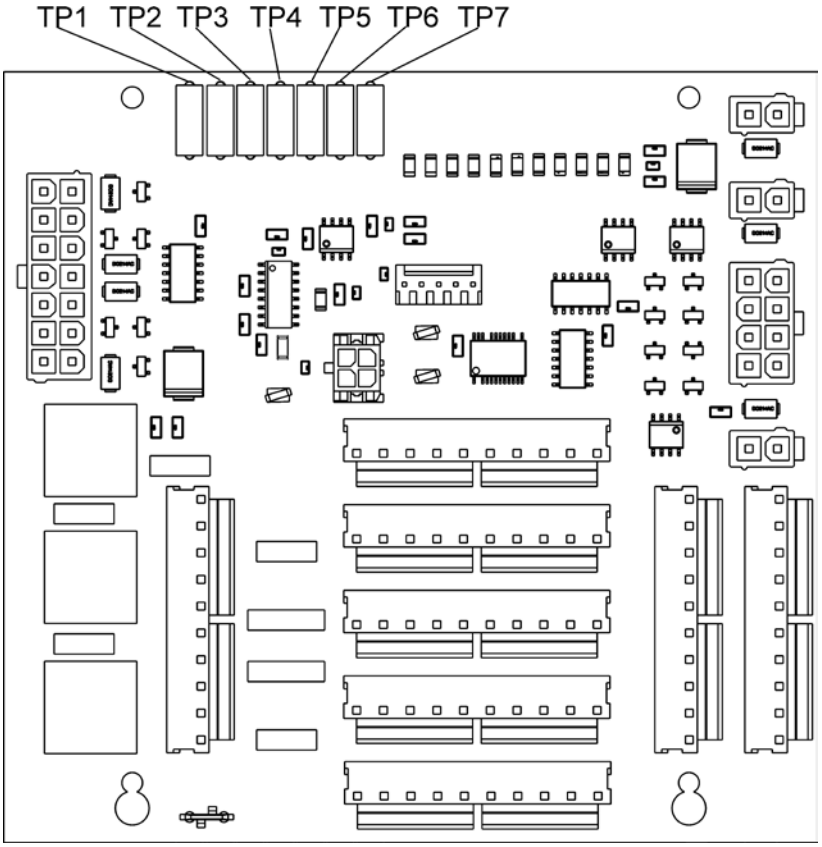


Figure 9-5: Location of DC Power Test Points on Relay PCA

Table 9-6: DC Power Test Point and Wiring Color Codes

NAME	TEST POINT#	TP AND WIRE COLOR
Dgnd	**1**	Black
+5V	**2**	Red
Agnd	**3**	Green
+15V	**4**	Blue
-15V	**5**	Yellow
+12R	**6**	Purple
+12V	**7**	Orange

A voltmeter should be used to verify that the DC voltages are correct per the values in Table 9-7, and an oscilloscope, in AC mode, with band limiting turned on, can be used to evaluate if the supplies are producing excessive noise (>100 mV p-p).

Table 9-7: DC Power Supply Acceptable Levels

POWER SUPPLY ASSY	VOLTAGE	CHECK RELAY PCA TEST POINTS				MIN V	MAX V
		FROM TEST POINT		TO TEST POINT			
		NAME	#	NAME	#		
PS1	+5	Dgnd	1	+5	2	4.8	5.25
PS1	+15	Agnd	3	+15	4	13.5	16V
PS1	-15	Agnd	3	-15V	5	-14V	-16V
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	11.75	12.5
PS2	Dgnd	+12V Ret	6	Dgnd	1	-0.05	0.05

9.4.4. I^2C BUS

Operation of the I^2C 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 I^2C 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 I^2C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

9.4.5. TOUCHSCREEN 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.

9.4.6. LCD TOUCHSCREEN MODULE

Verify the functioning of the LCD touchscreen 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/touchscreen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

9.4.7. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 9.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 4.10) to toggle each LED **ON** or **OFF.**

If D1 on the Relay PCA is flashing and the status indicator for the output in question (Heater power, Valve Drive, etc.) toggles properly using the Signal I/O function, then the associated control device on the Relay PCA is bad. Several of the control devices are in sockets and can be easily replaced. Table 9-8 lists the control device associated with a particular function.

Table 9-8: Relay PCA Control Devices

FUNCTION	CONTROL DEVICE	IN SOCKET
UV Lamp Heater	Q2	No
O_3 Gen Heater	Q3	No
All Valves	U5	Yes

9.4.8. INPUT GAS PRESSURE / FLOW SENSOR ASSEMBLY

The input gas pressure/flow sensor PCA (see Figure 3-4) can be checked with a voltmeter. The following procedure assumes that the wiring is intact and that the motherboard and the power supplies are operating properly:

BASIC PCA OPERATION:

- Measure the voltage across C1; it should be 5 VDC ± 0.25 VDC. If not, then the board is bad.

CAL GAS PRESSURE SENSOR:

1. Measure the pressure on the inlet side of S1 with an external pressure meter.
2. Measure the voltage across TP4 and TP1.
   - The expected value for this signal should be:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{34.18_{psig}} \text{ x } 4250_{mvDC}\right) + 750_{mvDC} \quad \pm 10\%_{rdg}$$

EXAMPLE: If the measured pressure is 25 PSIG, the expected voltage level between TP4 and TP1 would be between 3470 mVDC and 4245 mVDC.

EXAMPLE: If the measured pressure is 30 PSIG, the expected voltage level between TP4 and TP1 would be between 4030 mVDC and 4930 mVDC.

   - If this voltage is out of range, then either pressure transducer S1 is bad, the board is bad, or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly.

DILUENT PRESSURE SENSOR:

1. Measure the pressure on the inlet side of S2 with an external pressure meter.
2. Measure the voltage across TP5 and TP1.
   - Evaluate the reading in the same manner as for the cal gas pressure sensor.

9.4.9. PHOTOMETER O_3 GENERATOR PRESSURE/FLOW SENSOR ASSEMBLY

This assembly is only present in calibrators with O_3 generator and/or photometer options installed. The pressure/flow sensor PCA, located at the rear of the instrument between the O_3 generator and the photometer pump (see Figure 3-4) can be checked with a voltmeter. The following procedure assumes that the wiring is intact and that the motherboard and the power supplies are operating properly:

BASIC PCA OPERATION

- Measure the voltage across C1; it should be 5 VDC ± 0.25 VDC. If not then the board is bad
- Measure the voltage between TP2 and TP1 C1; it should be 1o VDC ± 0.25 VDC. If not then the board is bad.

PHOTOMETER PRESSURE SENSOR

1. Measure the pressure on the inlet side of S1 with an external pressure meter.
2. Measure the voltage across TP4 and TP1.
   - The expected value for this signal should be:

$$\text{Expected mVDC} = \left(\frac{\text{Pressure}}{30.0_{\text{In-Hg-A}}} \times 4660_{\text{mvDC}}\right) + 250_{\text{mvDC}} \quad \pm 10\%_{\text{rdg}}$$

EXAMPLE: If the measured pressure is 20 In-Hg-A, the expected voltage level between TP4 and TP1 would be between 2870 mVDC and 3510 mVDC.

EXAMPLE: If the measured pressure is 25 In-Hg-A, the expected voltage level between TP4 and TP1 would be between 3533 mVDC and 4318 mVDC.

   - If this voltage is out of range, then either pressure transducer S1 is bad, the board is bad or there is a pneumatic failure preventing the pressure transducer from sensing the absorption cell pressure properly.

O_3 GENERATOR PRESSURE SENSOR

1. Measure the pressure on the inlet side of S2 with an external pressure meter.
2. Measure the voltage across TP5 and TP1.
   - Evaluate the reading in the same manner as for the cal gas pressure sensor (see Section 9.4.8).

PHOTOMETER FLOW SENSOR

- Measure the voltage across TP3 and TP1.
  - With proper flow (800 cm3/min through the photometer), this should be approximately 4.5V (this voltage will vary with altitude).
  - With flow stopped (photometer inlet disconnected or pump turned OFF) the voltage should be approximately 1V.
  - If the voltage is incorrect, the flow sensor S3 is bad, the board is bad or there is a leak upstream of the sensor.

9.4.10. **MOTHERBOARD**

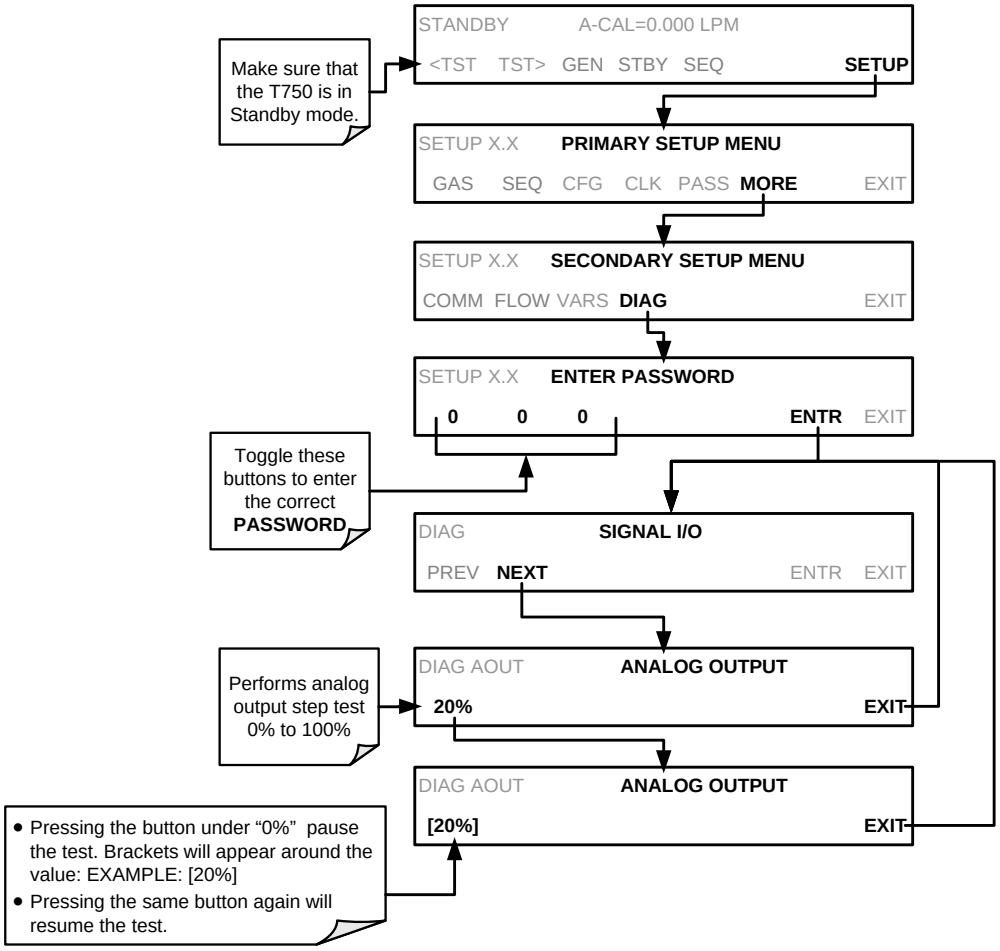
9.4.10.1. **A/D Functions**

The simplest method to check the operation of the A-to-D converter on the motherboard is to use the Signal I/O function under the DIAG menu; check the two A/D reference voltages and input signals that can be easily measured with a voltmeter.

1. Use the Signal I/O function (see Section 9.1.3 and Appendix A) to view the value of REF_4096_MV and REF_GND. If both are within 3 mV of nominal (4096 and 0), and are stable ±0.5 mV, then the basic A/D is functioning properly. If not, then the motherboard is bad.
2. Choose a parameter in the Signal I/O function such as Dil_PRess, MFC_FLOW_1 or SAMPLE_FLOW.
   - Compare these voltages at their origin (see the interconnect drawing and interconnect list in Appendix D) with the voltage displayed through the signal I/O function.
   - If the wiring is intact but there is a large difference between the measured and displayed voltage (±10 mV) then the motherboard is bad.

9.4.10.2. **Test Channel / Analog Outputs Voltage**

To verify that the analog output is working properly, connect a voltmeter to the output in question and perform an analog output step test using the following menu:



For each of the steps, the output should be within 1% of the nominal value listed in the table below except for the 0% step, which should be within 0mV ±2 to 3 mV. Ensure you take into account any offset that may have been programmed into channel (see Section 4.10.1.5).

Table 9-9: Analog Output Test Function – Nominal Values Voltage Outputs

		FULL SCALE OUTPUT OF VOLTAGE RANGE (see Section 4.10.1.3)			
		100MV	**1V**	**5V**	**10V**
STEP	**%**	**NOMINAL OUTPUT VOLTAGE**			
1	0	0	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

If one or more of the steps fails to be within these ranges, it is likely that there has been a failure of the either or both of the DACs and their associated circuitry on the motherboard.

9.4.10.3. **Status Outputs**

To test the status output electronics:

1. Connect a jumper between the "D" pin and the "▽" pin on the status output connector.
2. Connect a 1000 ohm resistor between the "+" pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the "▽" pin and the pin of the output being tested (see table below).
4. Under the DIAG→ Signal I/O menu (see Section9.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternatively, turn on and off the output noting the voltage on the voltmeter.
   - It should vary between 0 volts for ON and 5 volts for OFF.

Table 9-10: Status Outputs Check

PIN (LEFT TO RIGHT)	STATUS
1	ST_SYSTEM_OK
2	SPARE
3	ST_CAL_ACTIVE
4	ST_DIAG_MODE
5	ST_TEMP_ALARM
6	ST_PRESS_ALARM
7	PERM_VALVE_1
8	PERM_VALVE_2

9.4.10.4. **Control Inputs**

Table 9-11: T750 Control Input Pin Assignments and Corresponding Signal I/O Functions

CONNECTOR	INPUT	CORRESPONDING I/O SIGNAL
Top	**A**	**CONTROL_IN_1**
Top	**B**	**CONTROL_IN_2**
Top	**C**	**CONTROL_IN_3**
Top	**D**	**CONTROL_IN_4**
Top	**E**	**CONTROL_IN_5**
Top	**F**	**CONTROL_IN_6**
Bottom	**G**	**CONTROL_IN_7**
Bottom	**H**	**CONTROL_IN_8**
Bottom	**I**	**CONTROL_IN_9**
Bottom	**J**	**CONTROL_IN_10**
Bottom	**K**	**CONTROL_IN_11**
Bottom	**L**	**CONTROL_IN_12**

The control input bits can be tested by applying a trigger voltage to an input and watching changes in the status of the associated function under the SIGNAL I/O submenu:

EXAMPLE: to test the "**A**" control input:

1. Under the DIAG→ Signal I/O menu (see Section 9.1.3), scroll through the inputs and outputs until you get to the output named 0) CONTROL_IN_1.
2. Connect a jumper from the "+" pin on the appropriate connector to the "U" on the same connector.
3. Connect a second jumper from the "▽" pin on the connector to the "A" pin.
4. The status of 0) CONTROL_IN_1 should change to read "ON".

9.4.10.5. **Control Outputs**

To test the Control Output electronics:

1. Connect a jumper between the "E" pin and the "▽" pin on the status output connector.
2. Connect a 1000 ohm resistor between the "+" pin and the pin for the status output that is being tested.
3. Connect a voltmeter between the "▽" pin and the pin of the output being tested (see Table 9-12).
4. Under the DIAG→ Signal I/O menu (see Section 9.1.3), scroll through the inputs and outputs until you get to the output in question.
5. Alternately, turn on and off the output noting the voltage on the voltmeter.
   - It should vary between 0 volts for ON and 5 volts for OFF.

Table 9-12: Control Outputs Pin Assignments and Corresponding Signal I/O Functions Check

PIN (LEFT TO RIGHT)	STATUS
1	**CONTROL_OUT_1**
2	**CONTROL_OUT_2**
3	**CONTROL_OUT_3**
4	**CONTROL_OUT_4**
5	**CONTROL_OUT_5**
6	**CONTROL_OUT_6**
7	**CONTROL_OUT_7**
8	**CONTROL_OUT_8**
9	**CONTROL_OUT_9**
10	**CONTROL_OUT_10**
11	**CONTROL_OUT_11**
12	**CONTROL_OUT_12**

9.4.11. **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 occurs, 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, the watchdog LED on the motherboard is not flashing.

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 invalid.

If the analyzer stops during initialization (the LCD touchscreen shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

9.4.12. **THE CALIBRATOR DOESN'T APPEAR ON THE LAN OR INTERNET**

Most problems related to Internet communications via the Ethernet card will be due to problems external to the calibrator (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:

- Verify that the instrument is connected to an active network jack.
- Check the internal cable connection between the Ethernet card and the CPU board.

9.4.13. **RS-232 COMMUNICATIONS**

9.4.13.1. **General RS-232 Troubleshooting**

Teledyne API calibrators use the RS-232 communications protocol to allow the instrument to be connected to a variety of computer-based equipment. RS-232 has been used for many years and as equipment has become more advanced, connections between various types of hardware have become increasingly difficult. Generally, every manufacturer observes the signal and timing requirements of the protocol very carefully.

Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. See Section 3.4.1.6 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 5.2.
- If a modem is being used, additional configuration and wiring rules must be observed. See Section 6.3.
- Incorrect setting of the DTE-DCE Switch is set correctly. See Section 5.1.
- Verify that the cable (P/N 03596) that connects the serial COMM ports of the CPU to J12 of the motherboard is properly seated.

9.4.13.2. **Troubleshooting Calibrator/Modem or Terminal Operation**

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API calibrator.

1. Check cables for proper connection to the modem, terminal or computer.
2. Check to ensure the DTE-DCE is in the correct position as described in Section 5.1.
3. Check to ensure the set up command is correct. See Section 6.2.
4. Verify that the Ready to Send (RTS) signal is at logic high. The T750 sets pin 7 (RTS) to greater than 3 volts to enable modem transmission.
5. Ensure the BAUD rate, word length, and stop bit settings between modem and calibrator match. See Section 5.2.1.
6. Use the RS-232 test function to send “w” characters to the modem, terminal or computer. See Section 5.2.3.
7. Get your terminal, modem or computer to transmit data to the calibrator (holding down the space bar is one way); the green LED should flicker as the instrument is receiving data.
8. Ensure that the communications software or terminal emulation software is functioning properly.

Note **Further help with serial communications is available in a separate manual “RS-232 Programming Notes” Teledyne API’s P/N 013500000.**

9.4.14. TEMPERATURE PROBLEMS

Individual control loops are used to maintain the set point of the Photometer UV Lamp (optional), and the Ozone Generator Lamp (optional). If any of these temperatures are out of range or are poorly controlled, the T750 will perform poorly.

9.4.14.1. Box / Chassis Temperature

The box temperature sensor is mounted to the Motherboard and cannot be disconnected to check its resistance. Rather check the **BOX TEMP** signal using the **SIGNAL I/O** function under the **DIAG** Menu (see Section 9.1.3). This parameter will vary with ambient temperature, but at ~30°C (6-7° above room temperature) the signal should be ~1450 mV.

9.4.14.2. Photometer Sample Chamber Temperature

The temperature of the gas in the photometer sample chamber should read approximately 5.0°C higher than the box temperature.

9.4.14.3. UV Lamp Temperature

There are three possible causes for the UV Lamp temperature to have failed.

- The UV Lamp heater has failed. Check the resistance between pins 5 and 6 on the six-pin connector adjacent to the UV Lamp on the Optical Bench.
  - It should be approximately 30 Ohms.
- Assuming that the I^2C bus is working and that there is no other failure with the Relay board, the FET Driver on the Relay Board may have failed.
  - Using the PHOTO_LAMP HEATER parameter under the Signal I/O function of the Diag menu, as described above, turn on and off the UV Lamp Heater (D15 on the relay board should illuminate as the heater is turned on).
  - Check the DC voltage present between pin 1 and 2 on J13 of the Relay Board.
  - If the FET Driver has failed, there will be no change in the voltage across pins 1 and 2.
- If the FET Driver Q2 checks out OK, the thermistor temperature sensor in the lamp assembly may have failed.
  - Unplug the connector to the UV Lamp Heater/Thermistor PCB, and measure the resistance of the thermistor between pins 5 and 6 of the 6-pin connector.
  - The resistance near the 58oC set point is ~8.1k ohms.

9.4.14.4. **Ozone Generator Temperature**

There are three possible causes for the Ozone Generator temperature to have failed.

- The O_3 Gen heater has failed. Check the resistance between pins 5 and 6 on the six-pin connector adjacent to the UV Lamp on the O_3 Generator. It should be approximately 5 Ohms.
- Assuming that the I^2C bus is working and that there is no other failure with the Relay board, the FET Driver on the Relay Board may have failed. Using the **O3_GEN_HEATER** parameter under the **SIGNAL I/O** submenu of the **DIAG** menu as described above, turn the UV Lamp Heater on and off. Check the DC voltage present between pin 1 and 2 on J14 of the Relay Board.

  If the FET Driver has failed, there should be no change in the voltage across pins 1 and 2.
- If the FET Driver checks out OK, the thermistor temperature sensor in the lamp assembly may have failed. Unplug the connector to the Ozone Generator Heater/Thermistor PCB, and measure the resistance of the thermistor between pins 5 and 6 of the 6-pin connector.

9.5. TROUBLESHOOTING THE OPTIONAL O_3 PHOTOMETER

9.5.1. DYNAMIC PROBLEMS WITH THE OPTIONAL O_3 PHOTOMETER

Dynamic problems are problems that only manifest themselves when the photometer is measuring O_3 concentration gas mixtures. These can be the most difficult and time consuming to isolate and resolve.

Since many photometer behaviors that appear to be a dynamic in nature are often a symptom of a seemingly unrelated static problems, it is recommended that dynamic problems not be addressed until all static problems, warning conditions and subsystems have been checked and any problems found are resolved.

Once this has been accomplished, the following most common dynamic problems should be checked.

9.5.1.1. **Noisy or Unstable O_3 Readings at Zero**

- Check for leaks in the pneumatic system as described in Section 8.2.1.
- Confirm that the Zero gas is free of Ozone.
- Confirm that the Source Lamp is fully inserted and that the lamp hold-down thumbscrew is tight.
- Check for a dirty Absorption Cell and/or pneumatic lines. Clean as necessary as described in Section 8.2.2.
- Disconnect the exhaust line from the optical bench (the pneumatic line at the lamp end of the bench) and plug the port in the bench. If readings remain noisy, the problem is in one of the electronic sections of the instrument. If readings become quiet, the problem is in the instrument's pneumatics.

9.5.1.2. **Noisy, Unstable, or Non-Linear Span O_3 Readings**

- Check for leaks in the pneumatic systems as described in Section 8.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section 9.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 9.4.10.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.

9.5.1.3. **Slow Response to Changes in Concentration**

- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for pneumatic leaks as described in Section 8.2.1.
- The photometer needs 800 cm^3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 3.5.9).

9.5.1.4. **The Analog Output Signal Level Does Not Match LCD Touchscreen Readings**

- Confirm that the recorder offset (see Section 4.10.1.5) is set to zero.
- Perform an AIO calibration (see Section 4.10.1.6) and photometer dark calibration (see Section 7.3.5).

9.5.1.5. **Cannot Zero**

- Check for leaks in the pneumatic system as described in Section 8.2.1.
- Confirm that the Zero gas is free of Ozone.
- The photometer needs 800 cm^3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 3.5.9).

9.5.1.6. **Cannot Span**

- Check for leaks in the pneumatic systems as described in Section 8.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section9.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 8.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 9.4.10.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.

- The photometer needs 800 cm^3/min of gas flow. Ensure that this is accounted for when calculating total required output flow for the calibrator (see Section 3.5.9).

9.5.2. **CHECKING MEASURE / REFERENCE VALVE**

1. To check the function of the photometer's measure / reference valve:
2. Set the calibrator's LCD touchscreen to show the PHOTO REFERENCE test function (see Section 4.1.1).
3. Follow the instruction in Sections 7.3.3 and 7.3.4.1 for performing a zero point calibration of the photometer.
   - Press XZRO and allow the calibrator to stabilize.
4. Before completing the calibration by pressing the ZERO button, take note of the displayed value.
5. Press the final Zero button then press "NO" when asked, "ARE YOU SURE".
6. Follow the instruction in Sections 7.3.4.2 for performing a span point calibration of the photometer.
   - Press XSPN and allow the calibrator to stabilize.
7. Before completing the calibration by pressing the SPAN button, note of the displayed value of PHOTO REFERENCE.
   - If the O3 REF value has decreased by more than 2 mV from its value with Zero-gas, then there is a "cross-port" leak in the M/R valve.
8. Press the final Zero button then press "NO" when asked, "ARE YOU SURE".

9.5.3. CHECKING THE UV LAMP POWER SUPPLY

Note **A schematic and physical diagram of the Lamp Power Supply can be found in Appendix D.**

WARNING

Hazardous voltage present - use caution.

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

1. Unplug the cable connector at P1 on the Lamp Power Supply and confirm that +15VDC is present between Pins 1 and 2 on the cable connector.
2. If this voltage is incorrect, check the DC test points on the relay PCA as described in Section 9.4.3.
3. Remove the cover of the photometer and check for the presence of the following voltages on the UV lamp power supply PCA (see Figure 10-20):
   - +4500 mVDC ±10 mVDC between TP1 and TP4 (grnd)
   - If this voltage is incorrect, either the UV lamp power supply PCA is faulty or the I2C bus is not communicating with the UV lamp power supply PCA.
   - +5VDC between TP3 and TP4 (grnd)
   - If this voltages is less than 4.8 or greater than 5.25 either the 5 VDC power supply or the UV lamp power supply PCA are faulty.
   - If the above voltages check out, it is more likely that a problem is due to the UV Lamp than due to the Lamp Power Supply.
   - Replace the Lamp and if the problem persists, replace the Lamp Power Supply.

9.6. TROUBLESHOOTING THE OPTIONAL O_3 GENERATOR

The only significant components of the O_3 generator that might reasonable malfunction is the power supply assembly for the UV source lamp and the lamp itself.

9.6.1. CHECKING THE UV SOURCE LAMP POWER SUPPLY

Note **Appendix D includes a schematic of the Lamp Power Supply.**

WARNING
Hazardous voltage present - use caution.

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

1. Ensure that the calibrator is in STANDBY mode.
2. Unplug the cable connector at P1 on the Lamp Power Supply and confirm that +15VDC is present between Pins 1 and 2 on the cable connector.
3. If this voltage is incorrect, check the DC test points on the relay PCA as described in Section 9.4.3.
4. Remove the cover of the photometer and check for the presence of the following voltages on the UV lamp power supply PCA (see Figure 10-20):
   - +800 mVDC ±10 mVDC between TP1 and TP4 (grnd)
   - If this voltage is incorrect, either the UV lamp power supply PCA is faulty or the I2C bus is not communicating with the UV lamp power supply PCA.
   - +5VDC between TP3 and TP4 (grnd)
   - If this voltages is less than 4.8 or greater than 5.25 either the 5 VDC power supply or the UV lamp power supply PCA are faulty.
   - If the above voltages check out, it is more likely that a problem is due to the UV Lamp than due to the Lamp Power Supply.
   - Replace the Lamp and if the problem persists, replace the Lamp Power Supply.

9.7. SERVICE PROCEDURES

9.7.1. DISK-ON-MODULE REPLACEMENT PROCEDURE

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it may also cause some of the instrument configuration parameters to be lost 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, open the communications and output panel (Figure 3-5).
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 standoff clip 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 communications and output panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

9.8. TECHNICAL ASSISTANCE

If this manual and its service & repair section do not solve your problems, technical assistance may be obtained from:

TELEDYNE API, TECHNICAL SUPPORT,
9970 CARROLL CANYON ROAD
SAN DIEGO, CALIFORNIA 92131-1106
USA

Toll-free Phone:	**800-324-5190**
Phone:	**+1 858-657-9800**
Fax:	**+1 858-657-9816**
Email:	**sda_techsupport@teledyne.com**
Website:	**http://www.teledyne-api.com/**

Before you contact Technical Support, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.teledyne-api.com/forms/.

9.9. FREQUENTLY ASKED QUESTIONS (FAQs)

The following list of FAQs is from the Teledyne API's Technical Support Department's most commonly asked questions relating to the T750 Portable Calibrator.

Question	Answer
My ozone ACT =XXXX why?	Look at the Photo Ref/Meas. These are most likely too low and need to be adjusted up to 4500mV. Another possible cause would be no gas flow to the photometer causing the O_3 reading to be out of range - low
When I generate ozone, it takes a long time to settle out or it fluctuates around the number until finally stabilizing.	Perform an O_3 Gen Adjust (Section 8.2.5), and then an O_3 Gen Calibration (Section 7.4). Re-run points.
Why does the **ENTR** button sometimes disappear on the LCD touchscreen?	Once you adjust the setting to an allowable value, the **ENTR** button will re-appear.
How do I make the RS-232 Interface Work?	See Sections 3.4.1.6, 5, and 9.4.13
When should I change the sintered filter(s) in the calibrator's critical flow orifice(s) and how do I change them?	The sintered filters do not require regular replacement. Should one require replacement as part of a troubleshooting or repair exercise, contact Technical Support.
How often should I rebuild the photometer pump on my calibrator?	It does not require rebuilding; the entire pump should be replaced every two years.
How long do the UV lamps of the optional O_3 generator and photometer last?	The typical lifetime is about 2-3 years.

10. PRINCIPLES OF OPERATION

10.1. BASIC PRINCIPLES OF DYNAMIC DILUTION CALIBRATION

The T750 Portable Calibrator generates calibration gas mixtures by mixing bottled source gases of known concentrations with a diluent gas (zero air). Using several Mass Flow Controllers (MFCs) the T750 calibrator creates exact ratios of diluent and source gas by controlling the relative rates of flow of the various gases, under conditions where the temperature and pressure of the gases being mixed is known (and therefore the density of the gases).

The CPU calculates both the required source gas and diluent gas flow rates and controls the corresponding mass flow controllers by the following equation.

Equation 10-1

$$C_f = C_i \times \frac{GAS_{flow}}{Totalflow}$$

WHERE:

C_f = final concentration of diluted gas

C_i = source gas concentration

GAS_{flow} = source gas flow rate

Totalflow = the total gas flow through the calibrator

Totalflow is determined as:

Equation 10-2a

$$\mathbf{TOTALFLOW} = GAS_{flow} + Diluent_{flow}$$

WHERE:

GAS_{flow} = source gas flow rate

$Diluent_{flow}$ = zero air flow rate

For instrument with multiple source gas MFC total Flow is:

Equation 10-2b

$$\mathbf{TOTALFLOW} = GAS_{flow\ MFC1} + GAS_{flow\ MFC2} \ldots + GAS_{flow\ MFCn} + Diluent_{flow\ rate}$$

This dilution process is dynamic. The T750's CPU not only keeps track of the temperature and pressure of the various gases, but also receives data on actual flow rates of the various MFCs in real time so the flow rate control can be constantly adjusted to maintain a stable output concentration.

The T750 calibrator's level of control is so precise that bottles of mixed gases can be used as source gas. Once the exact concentrations of all of the gases in the bottle are programmed into the T750, it will create an exact output concentration of any of the gases in the bottle.

10.1.1. GAS PHASE TITRATION MIXTURES FOR O_3 AND NO_2

Because ozone is a very reactive and therefore under normal ambient conditions a short-lived gas, it cannot be reliably bottled, however, an optional O_3 generator can be included in the T750 calibrator, which allows the instrument to be used to create calibration mixtures that include O_3.

This ability to generate O_3 internally also allows the T750 Portable Calibrator to be used to create calibration mixture containing NO_2 using a gas phase titration process (GPT) by precisely mixing bottled NO of a known concentration with O_3 of a known n concentration and diluent gas (zero air).

The principle of GPT is based on the rapid gas phase reaction between NO and O_3 that produces quantities of NO_2 as according to the following equation:

Equation 10-3

$$NO + O_3 \longrightarrow NO_2 + O_2 + h\nu_{(light)}$$

Under controlled circumstances, the NO-O_3 reaction is very efficient (<1% residual O_3), therefore the concentration of NO_2 resulting from the mixing of NO and O_3 can be accurately predicted and controlled as long as the following conditions are met:

- The amount of O_3 used in the mixture is known.
- The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O_3 in the mixture.
- The volume of the mixing chamber is known.
- The NO and O_3 flow rates (from which the time the two gases are in the mixing chamber) are low enough to give a residence time of the reactants in the mixing chamber of >2.75 ppm min.

Given the above conditions, the amount of NO_2 being output by the T750 will be equal to (at a 1:1 ratio) the amount of O_3 added.

Since:

- The O_3 flow rate of the T750's O_3 generator is a fixed value (typically about 0.105 LPM);
- The GPT chamber's volume is known,
- The source concentration of NO is a fixed value,

Once the **TOTALFLOW** is determined and entered into the T750's memory and target concentration for the O_3 generator are entered into the calibrator's software, the T750 adjusts the NO flow rate and diluent (zero air) flow rate to precisely create the appropriate NO_2 concentration at the output.

In this case, ***Totalflow*** is calculated as:

Equation 10-4

$$DIL_{flow} = Totalflow - NO\,GAS_{flow} - O_{3\,flow}$$

WHERE:

$NOGAS_{flow}$ = NO source gas flow rate (For calibrator's with multiple source gas MFC, $NOGAS_{flow}$ is the sum of the flow rate for all of the active cal gas MFCs)

$Totalflow$ = total gas flow requirements of the system.

$O_{3\,flow}$ = the flow rate set for the O_3 generator.

DIL_{flow} = required diluent gas flow

Again, this is a dynamic process. An optional photometer can be added the T750 calibrator that allows the CPU to tracks the chemiluminescent reaction created when the NO and O_3 interact to measure the decrease in NO concentration as NO_2 is produced. This information, along with the other data (gas temperature and pressure, actual flow rates, etc.) is used by the CPU to establish a very accurate NO_2 calibration mixture.

10.2. PNEUMATIC OPERATION

The T750 calibrator pneumatic system is comprised of the precision dilution system and valve manifold consisting of one gas port valve and one diluent valve. These valves open and close off gas flow from the zero air and bottles upstream of the MFCs.

IMPORTANT

IMPACT ON READINGS OR DATA

Exceeding 35 PSI may cause leakage that could cause unwanted gases to be included in the calibration mixture. Each valve is rated for up to 40 PSI zero air pressure and the source gas pressure should be between 25 to 30 PSI and never more than 35 PSI.

For an instrument with the O_3 generator and GPT pneumatics installed, a glass volume, carefully selected per the U.S. E.P.A. guidelines is used to optimize NO_2 creation.

See Figure 3-18 and Section 3.4.2 for descriptions of the internal pneumatics for the T750 calibrator.

10.2.1. GAS FLOW CONTROL

The precision of gas flow through the T750 Portable Calibrator is centrally critical to its ability to mix calibration gases accurately. This control is established in several ways.

10.2.1.1. Diluent and Source Gas Flow Control

Diluent and source gas flow in the T750 calibrator is a directly and dynamically controlled by using highly accurate Mass Flow Controller. These MFCs include internal sensors that determine the actual flow of gas though each and feedback control circuitry that uses this data to adjust the flow as required. The MFCs consist of a shunt, a sensor, a solenoid valve and the electronic circuitry required to operate them.

The shunt divides the gas flow such that the flow through the sensor is a precise percentage of the flow through the valve. The flow through the sensor is always laminar.

The MFCs internal sensor operates on a unique thermal-electric principle. A metallic capillary tube is heated uniformly by a resistance winding attached to the midpoint of the capillary. Thermocouples are welded at equal distances from the midpoint of the tube. At zero air flow the temperature of both thermocouples will be the same. When flow occurs through the tubing, heat is transferred from the tube to the gas on the inlet side and from the gas back to the tube on the outlet side creating an asymmetrical temperature distribution. The thermocouples sense this decrease, increase of temperature in the capillary tube, and produce a mVDC output signal proportional to that change that is proportional to the rate of flow through the MFCs valve.

The electronic circuitry reads the signal output by the thermal flow sensor measured through a capillary tube. This signal is amplified so that it is varies between 0.00 VDC and 5.00 VDC. A separate 0 to 5 VDC command voltage is also generated that is proportional to the target flow rate requested by the T750's CPU. The 0-5VDC command signal is electronically subtracted from the 0-5VDC flow signal. The amount and direction of the movement is dependent upon the value and the sign of the differential signal.

The MFCs valve is an automatic metering solenoid type; its height off the seat is controlled by the voltage in its coil. The controller's circuitry amplifies and the differential signal obtained by comparing the control voltage to the flow sensor output and uses it to drive the solenoid valve.

The entire control loop is set up so that as solenoid valve opens and closes to vary the flow of gas through the shunt, valve and sensor in an attempt to minimize the differential between the control voltage for the target flow rate and the flow sensor output voltage generated by the actual flow rate of gas through the controller.

This process is heavily dependent on the capacity of the gas to heat and cool. Since the heat capacity of many gases is relatively constant over wide ranges of temperature and pressure, the flow meter is calibrated directly in molar mass units for known gases (see Section 3.5.6.3). Changes in gas composition usually only require application of a simple multiplier to the air calibration to account for the difference in heat capacity and thus the flow meter is capable of measuring a wide variety of gases.

10.2.1.2. **Flow Control Assemblies for Optional O_3 Components**

Whereas the gas flow rates for the final mixing of gases is controlled directly by the calibrator's MFCS, under direction of the CPU, other gas flow rates in the calibrator are set by various flow control assemblies located in the gas stream(s). These orifices are not adjusted but maintain precise volumetric control as long as the a critical pressure ratio is maintained between the upstream and the downstream orifice.

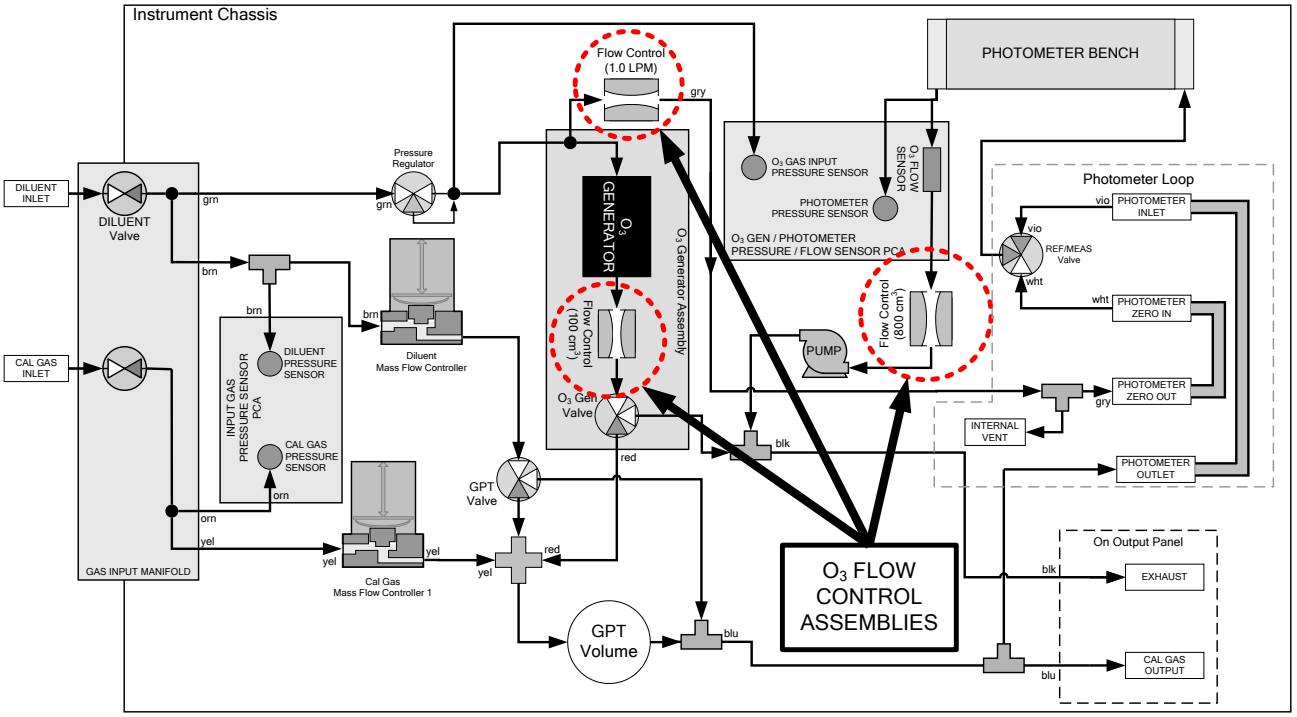


Figure 10-1: Location of Gas Flow Control Assemblies for T750's with O_3 Options Installed

The flow orifice assemblies consist 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.

10.2.1.3. **Critical Flow Orifices**

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 though the orifice, a pressure differential is created. This pressure differential combined with the action of the calibrator'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 though 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.

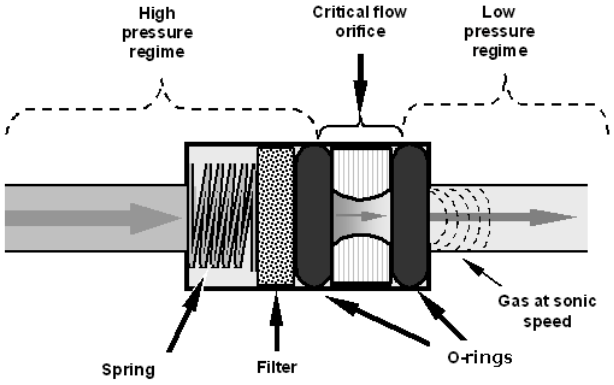


Figure 10-2: Flow Control Assembly & Critical Flow Orifice

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 a nominal pressure of 10 in-Hg-A in the sample/reaction cell, the necessary ratio of reaction cell pressure to pump vacuum pressure of 2:1 is exceeded and accommodating a wide range of variability in atmospheric pressure and accounting for pump degradation. This extends the useful life of the pump. Once the pump degrades to the point where the sample and vacuum pressures is less than 2:1, a critical flow rate can no longer be maintained.

10.2.2. **INTERNAL GAS PRESSURE SENSORS**

The T750 includes a single pressure regulator. Depending upon how many and which options are installed in the T750 calibrator, there are between two and four pressure sensors installed as well.

In the basic unit a printed circuit, assembly located near the front of the calibrator near the MFCs includes sensors that measure the pressure of the diluent gas and the source gas currently selected to flow into the calibrator. The calibrator monitors these sensors.

- Should the pressure of one of them fall below 15 PSIG or rise above 36 PSIG a warning is issued.

In units with the optional O_3 generator installed a second PCA located at the rear of the calibrator just behind the generator assembly includes a sensor that measures the gas pressure of the zero air flowing into the generator. A regulator is also located on the gas input to the O_3 generator that maintains the pressure differential needed for the critical flow orifice to operate correctly.

- Should the pressure of one of this sensor fall below 15 PSIG or rise above 25 PSIG a warning is issued.

In calibrators with O_3 photometers installed, a second pressure located on the rear PCA measures the pressure of gas in the photometer's absorption tube. This data is used by the CPU when calculating the O_3 concentration inside the absorption tube.

10.3. ELECTRONIC OPERATION

10.3.1. OVERVIEW

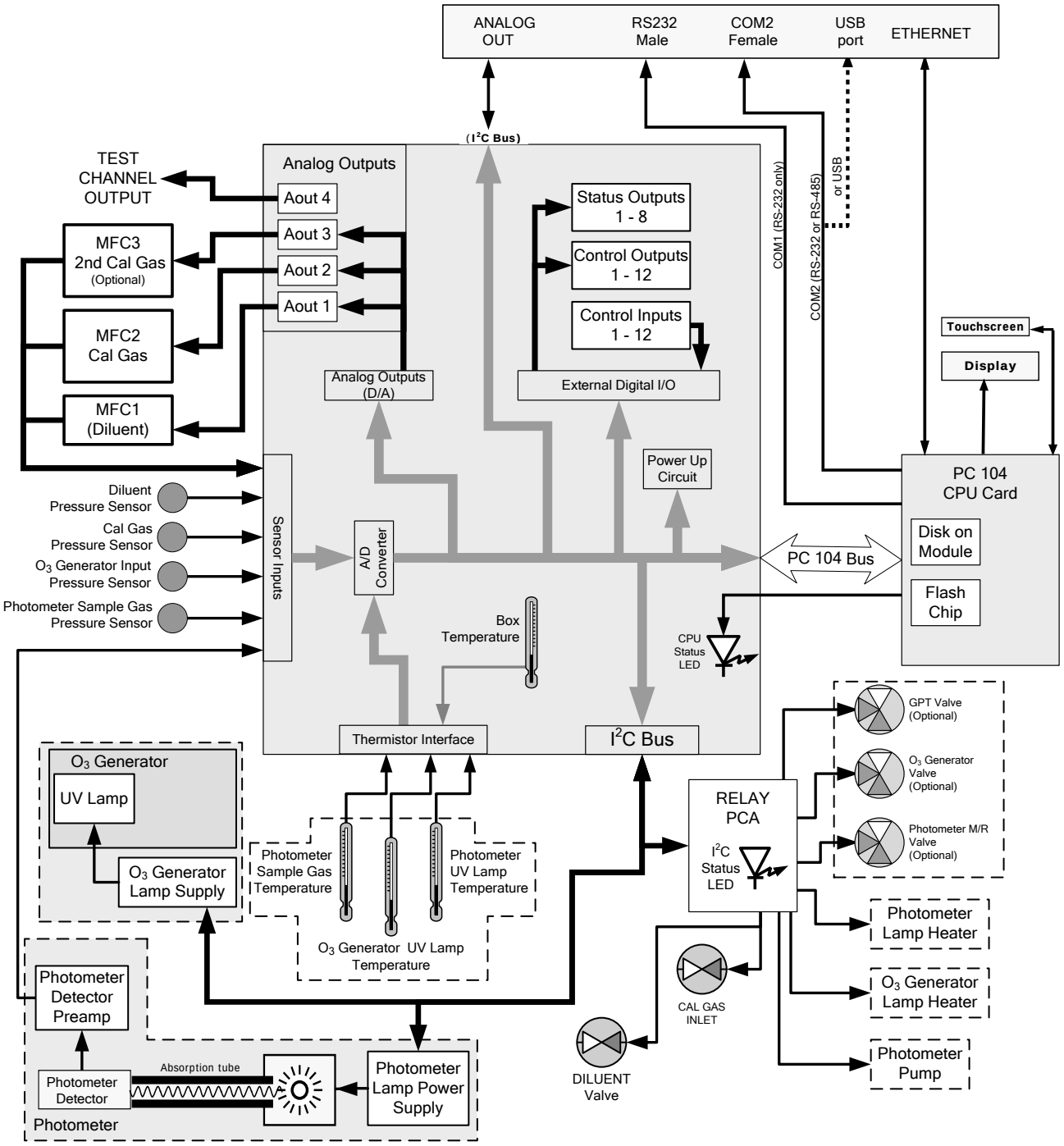


Figure 10-3: T750 Electronic Block Diagram

The core of the calibrator is a microcomputer (referred to as the CPU) that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as

well as receives data from and issues commands to a variety of peripheral devices via a separate printed circuit assembly called the motherboard.

The motherboard is directly mounted to the inside communications and output panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the calibrator's other major components.

Data are generated by the various sub components of the T750 (e.g. flow data from the MFCs, O_3 concentration from the optional photometer). Analog signals are converted into digital data by a unipolar, analog-to-digital converter, located on the motherboard.

A variety of sensors report the physical and operational status of the calibrator's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the concentration calculations and as trigger events for certain control commands issued by the CPU. They are stored in memory by the CPU and in most cases can be viewed but the user via the LCD touchscreen.

The CPU communicates with the user and the outside world in a variety of manners:

- Through the calibrator's LCD touchscreen interface;
- RS 232 and RS485 serial I/O channels;
- Via Ethernet;
- Various digital and analog outputs, and
- A set of digital control input channels.

Finally, the CPU issues commands via a series of relays and switches (also over the I^2C bus) located on a separate printed circuit assembly to control the function of key electromechanical devices such as heaters, motors and valves.

10.3.2. **CPU**

The unit's CPU card (Figure 10-4) is installed on the motherboard located inside the communications and output panel. It is a low power (5 VDC, 720mA max), high performance, Vortex86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC-104 specification and features the following:

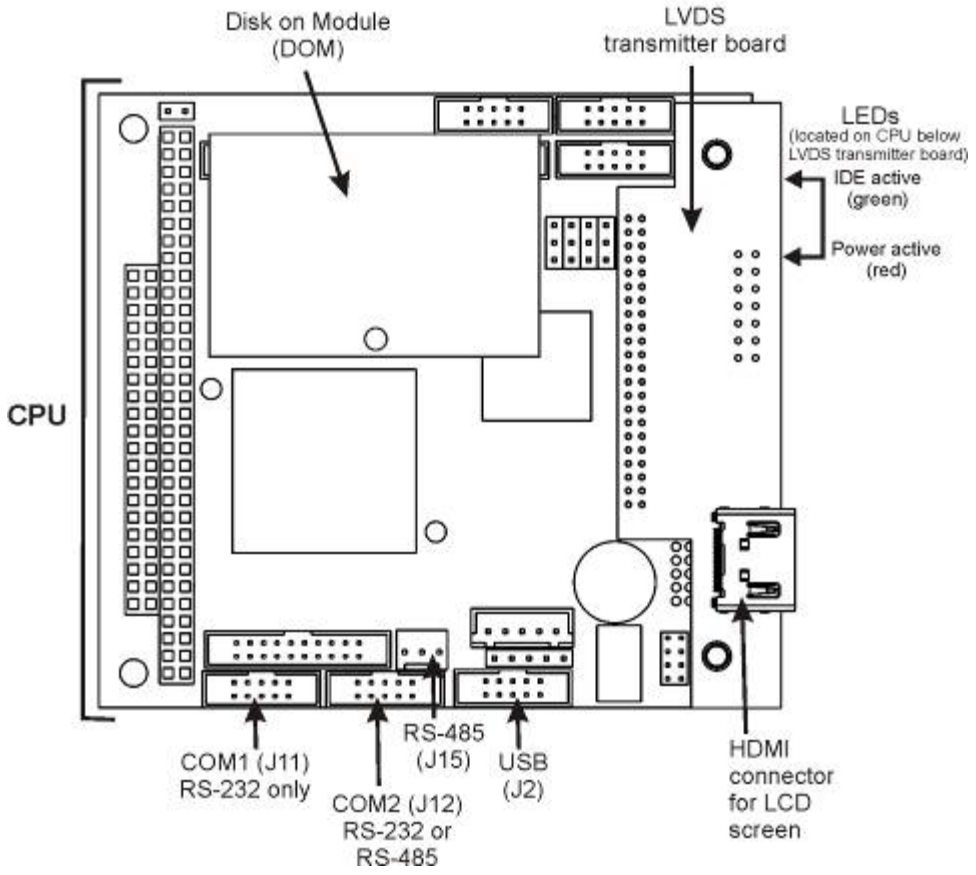


Figure 10-4: T750 CPU Board Annotated

The CPU includes two types of non-volatile data storage: an embedded 2MB flash chip and a Disk on Module (DOM).

10.3.2.1. Disk-on-Module (DOM)

The DOM is a 44-pin IDE flash chip with a storage capacity up to 256 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data. The LEDs on the DOM indicate power and reading/writing to or from the DOM.

10.3.2.2. Flash Chip

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the instrument's 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 calibrator will continue to operate with just the DOM. However, all configuration information will be lost, requiring the unit to be recalibrated.

10.3.3. **RELAY PCA**

The Relay PCA is one of the central switching and power distribution units of the calibrator. 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 calibrator. The relay PCA communicates with the motherboard over the I^2C bus and can be used for detailed trouble-shooting of power problems and valve or heater functionality.

The Relay PCA is mounted on the AC cage highlighted in Figure 10-6.

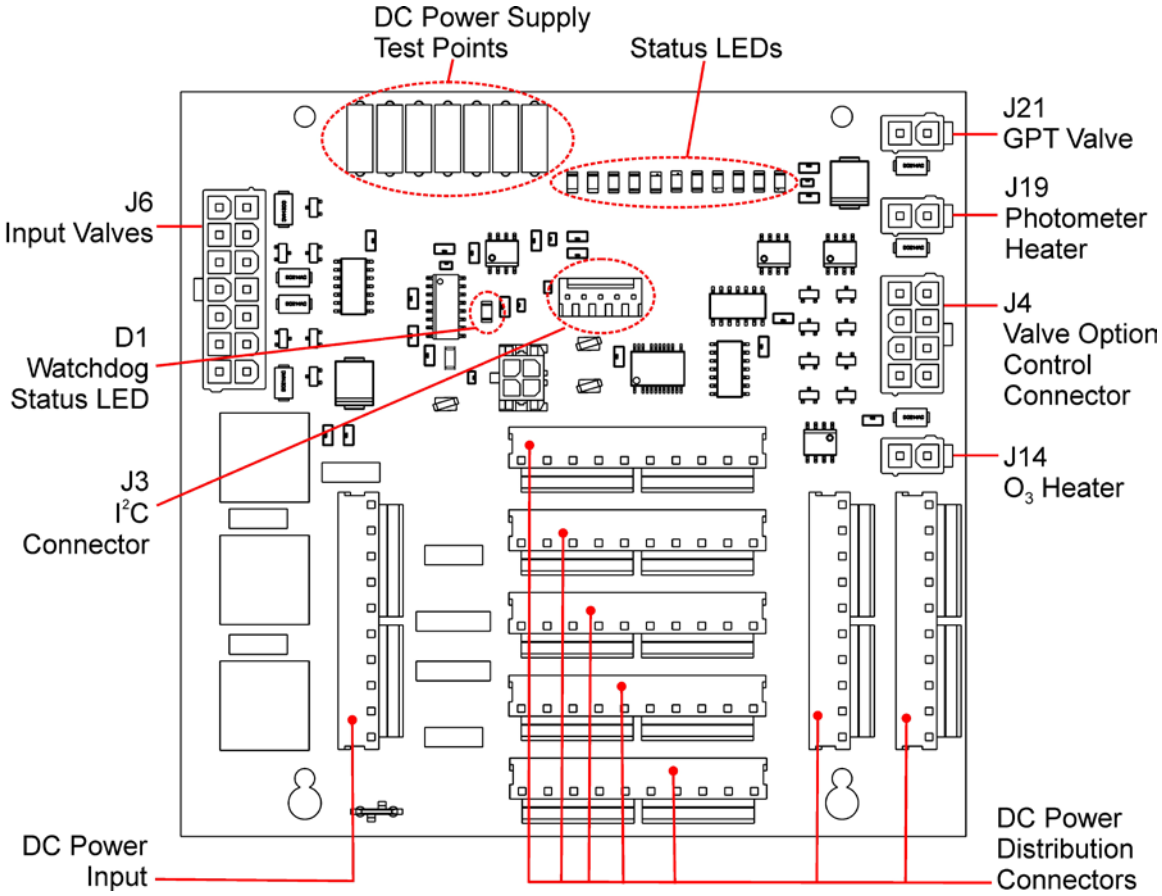


Figure 10-5: Relay PCA

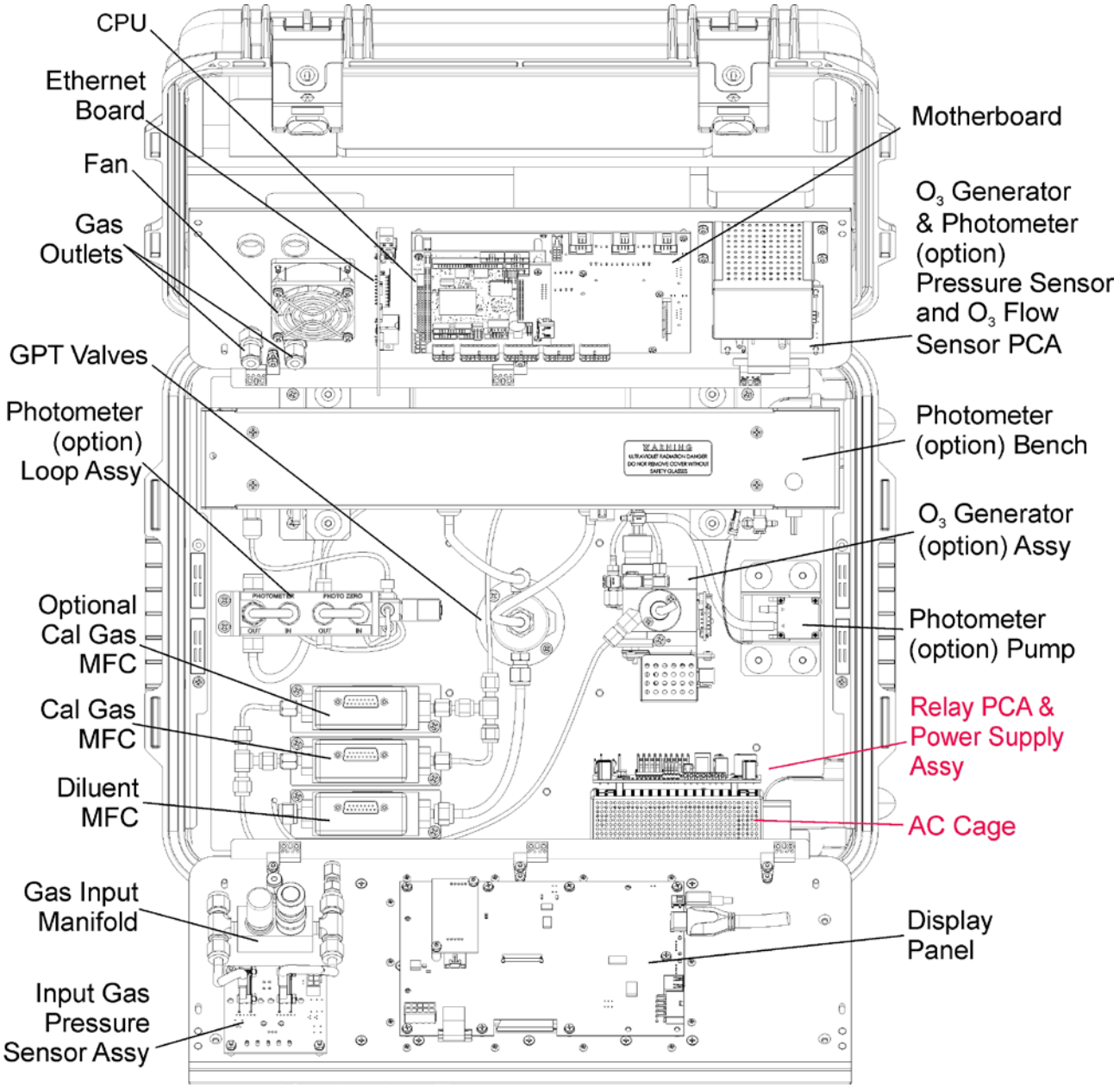


Figure 10-6: Relay PCA Location

WARNING

NEVER REMOVE THIS SAFETY SHIELD WHILE THE INSTRUMENT IS PLUGGED IN AND TURNED ON. THE CONTACTS OF THE AC RELAY SOCKETS BENEATH THE SHIELD CARRY HIGH AC VOLTAGES EVEN WHEN NO RELAYS ARE PRESENT

10.3.3.1. **Valve Control**

The relay PCA also hosts two valve driver chips, each of which can drive up to four valves. The relay PCA controls all the valves related to source gas and diluent gas flow. It also controls those associated with the O_3 generator and photometer options.

10.3.3.2. **Heater Control**

The relay PCA controls the various DC heaters related to the O_3 generator and photometer options.

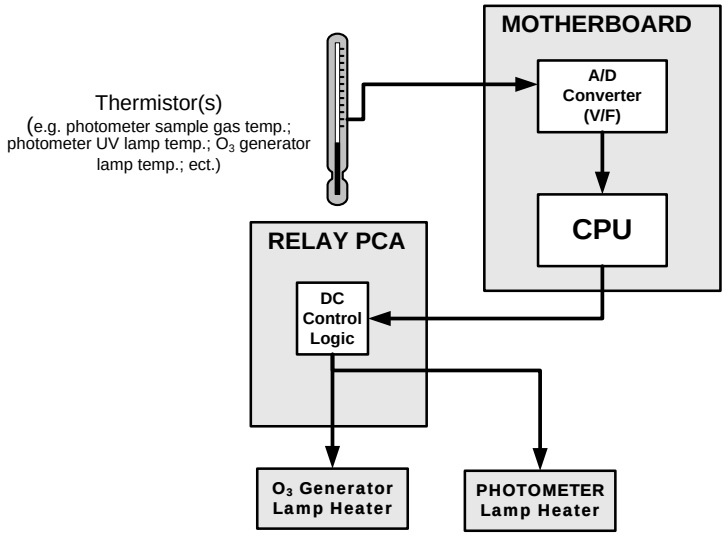


Figure 10-7: Heater Control Loop Block Diagram.

10.3.3.3. **Relay PCA Status LEDs & Watch Dog Circuitry**

Eleven LEDs are located on the calibrator's Relay PCA to indicate the status of the calibrator's heating zones, valves, and photometer option pump, as well as a general operating watchdog indicator. Table 10-1 describes these LEDs and their respective functions.

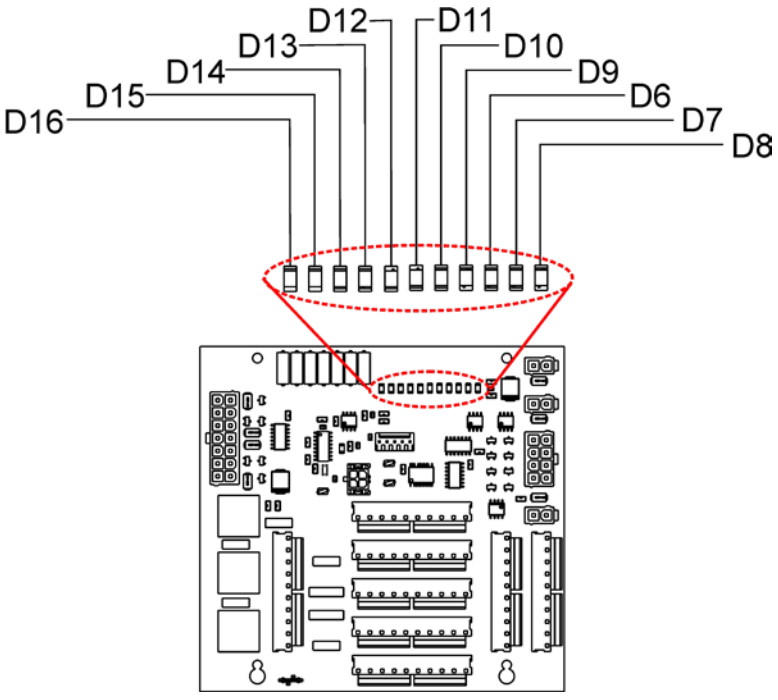


Figure 10-8: Status LED Locations – Relay PCA

Table 10-1: Relay PCA Status LEDs

LED	DESCRIPTION	FUNCTION
D1	Watchdog Circuit; I^2C bus operation.	Blinks when I^2C bus is operating properly
D2-6	SPARE	
D7[1]	Photometer Meas/Ref Valve	When lit, the valve opens the REFERENCE gas path
D8[2]	O_3 Generator Valve status	When lit, the valve open to O_3 generator gas path
D9	Photometer Pump status	When lit, the pump is turned on.
D6[1,2]	GPT Valve status	When lit, the valve opens the GPT Chamber
D13	Diluent Gas Valve status	When lit, the valve is open.
D10	Cal Gas Valve status	When lit, the valve is open.
D10 - 14	SPARE	
D15[1]	Photometer Heater Status	When lit, the photometer UV lamp heater is on
D16[2]	O_3 Generator Heater Status	When lit, the O_3 generator UV lamp heater is on

[1] Only applies on calibrators with photometer option installed.
[2] Only applies on calibrators with O_3 generator option installed.

10.3.3.4. **Relay PCA Watchdog Indicator (D1)**

The most important of the status LEDs on the relay PCA is the red I^2C Bus watchdog LED. It is controlled directly by the calibrator's CPU over the I^2C 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 I^2C bus has stopped functioning) this Watchdog Circuit automatically shuts all valves and turns off all heaters and lamps.

10.3.4. MOTHERBOARD

This is the largest electronic assembly in the calibrator and is mounted to the communications and output 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 I^2C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

10.3.4.1. A to D Conversion

Analog signals, such as the voltages received from the calibrator'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 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 and outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope, then uses these factors for subsequent calculations.

10.3.4.2. 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 kΩ) on each of the inputs prevent crosstalk between the sensor signals.

10.3.4.3. Thermistor Interface

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the calibrator.

10.3.4.4. Analog Outputs

The T750 calibrator comes equipped with one analog output. It can be set by the user to output a signal level representing any one of the test parameters (see Table 4-14) and will output an analog VDC signal that rises and falls in relationship with the value of the chosen parameter.

10.3.4.5. 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 communications and output panel of the calibrator. These outputs convey on/off information about certain calibrator conditions such as **SYSTEM OK**. They can be used to interface with certain types of programmable devices.

The **CONTROL** outputs can be used to initiate actions by external peripheral devices in conjunction with individual steps of a calibration sequence (see Section 4.3.2.4).

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 4.3.1.5). Zero and span calibrations can be initiated by contact closures on the communications and output panel.

10.3.4.6. I^2C Data Bus

I^2C is a two-way, 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 I^2C. The data is then fed to the relay board circuitry.

10.3.4.7. Power-up Circuit

This circuit monitors the +5V power supply during calibrator start-up and sets the analog outputs, external digital I/O ports, and I^2C circuitry to specific values until the CPU boots and the instrument software can establish control.

10.3.5. INPUT GAS PRESSURE SENSOR PCA

This PCA, physically located to the just to the left of the MFCs, houses two pressure sensors that measure the pressure of the incoming diluent gas (zero air) and calibration gases relative to ambient pressure. Pneumatically, both sensors measure their respective gases just upstream from the associated MFC.

This data is used in calculating the concentration of calibration mixtures.

The following TEST functions are viewable from the instrument's LCD touchscreen:

- **CALPRESS** - the pressure of the selected calibration gas input reported in **PSIG.**
- **DILPRESS** - the pressure of the diluent gas (zero air) input also reported in **PSIG.**

10.3.6. **POWER SUPPLY AND CIRCUIT BREAKER**

The T750 calibrator operates in two main AC power ranges: 100-120 VAC and 220-240 VAC (both ± 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 calibrator.

WARNING
The T750 calibrator is equipped with a universal power supply that allows it to accept any AC power configuration, within the limits specified in Table 2-2.

Should the power circuit breaker trip correct the condition causing this situation before turning the calibrator back on.

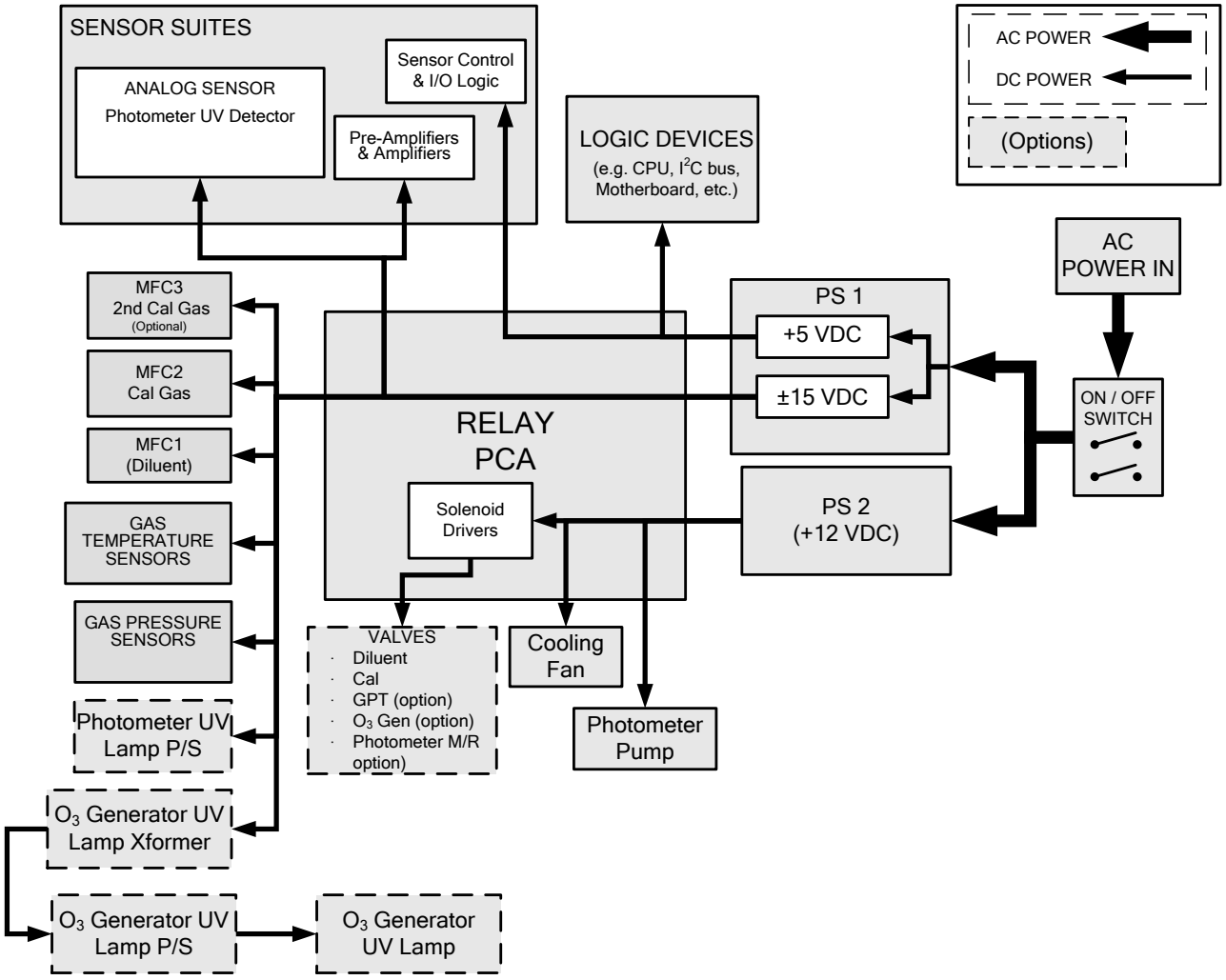


Figure 10-9: T750 Power Distribution Block diagram

10.4. TOUCHSCREEN/DISPLAY INTERFACE

The most commonly used method for communicating with the T750 Portable Calibrator is via the instrument's LCD touchscreen from where users can input data and receive information directly.

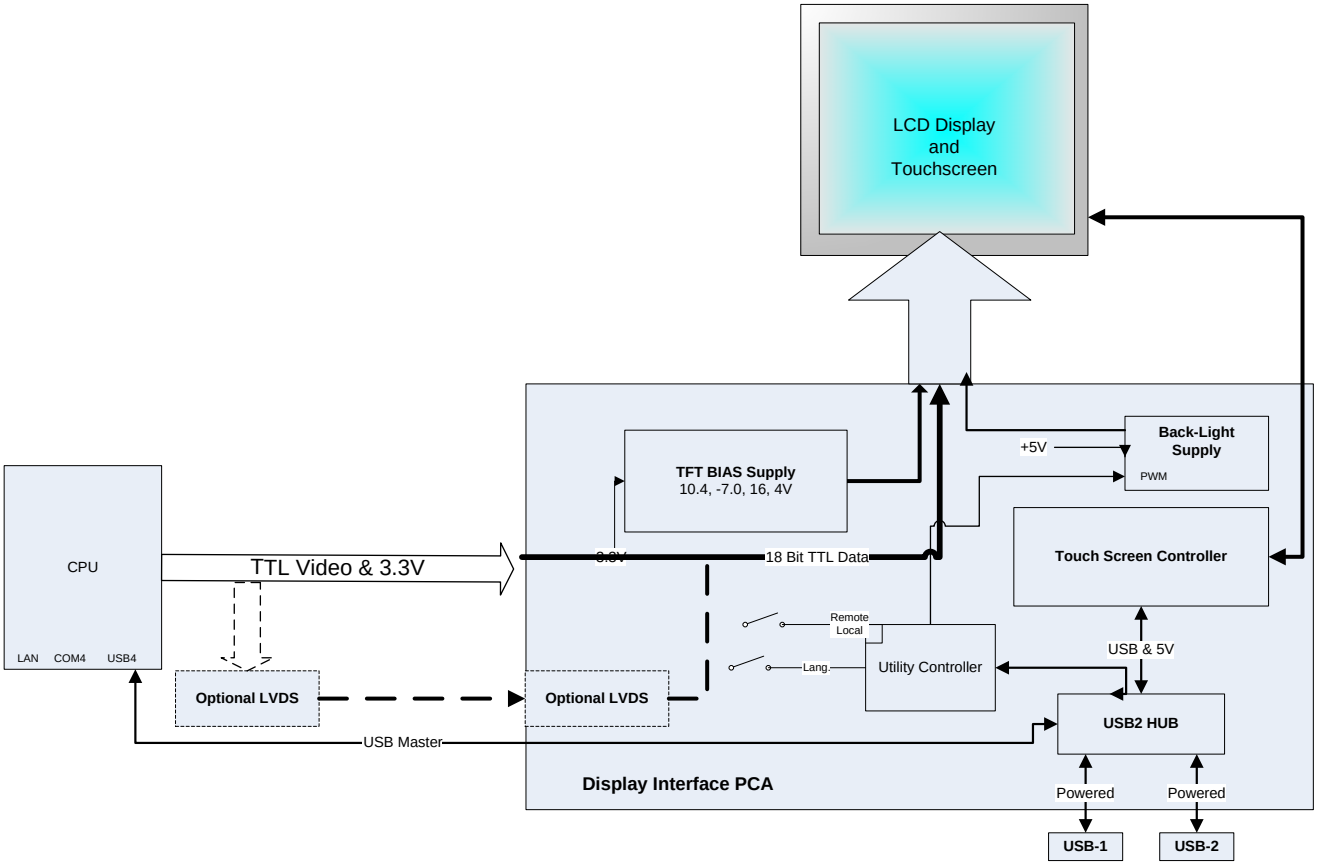


Figure 10-10: Display Interface Block Diagram

The LCD touchscreen is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.

10.4.1.1. Display Interface PCA

The display interface PCA controls the various functions of the control/display screen. This PCA provides connection between the CPU video controller and the LCD touchscreen module to drive the display. This PCA also contains:

- power supply circuitry for the LCD touchscreen module
- a USB hub that is used for communications with the touchscreen controller and the two USB device ports on the input panel
- the circuitry for powering the display backlight

10.5. SOFTWARE OPERATION

The T750 calibrator's core module is a high performance, X86-based microcomputer running Windows CE. On top of the Windows CE shell, special software developed by Teledyne API interprets user commands from various interfaces, performs procedures and tasks and stores data in the CPU's memory devices. Figure 10-11 shows a block diagram of this software functionality.

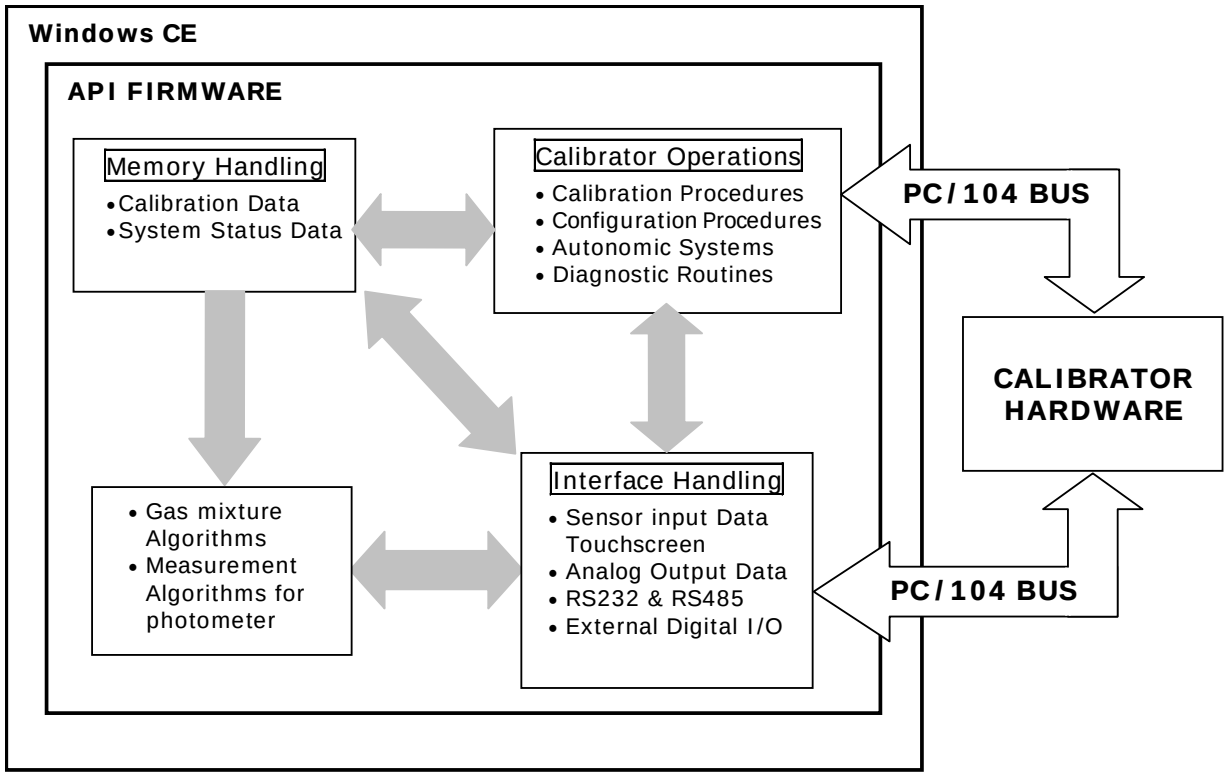


Figure 10-11: Schematic of Basic Software Operation

10.6. O_3 GENERATOR OPERATION

10.6.1. PRINCIPLE OF PHOTOLYTIC O_3 GENERATION

Ozone is a naturally occurring substance that is sometimes called "activated oxygen". It contains three atoms of oxygen (O_3) instead of the usual two found in normal oxygen (O_2) that is essential for life. Because of its relatively short half-life, ozone cannot be bottled and stored for later use and therefore must always be generated on-site by an ozone generator. The two main principles of ozone generation are UV-light and corona discharge. While the corona-discharge method is most common because of its ability to generate very high concentrations (up to 50%), it is inappropriate for calibration needs since the level of fine control over the O_3 concentration is poor. Also, the corona-discharge method produces a small amount of NO_2 as a byproduct, which also may be undesirable in a calibration application.

The UV-light method is most feasible in calibration applications where production of low, accurate concentrations of ozone desired. This method mimics the radiation method that occurs naturally from the sun in the upper atmosphere producing the ozone layer. An ultra-violet lamp inside the generator emits a precise wavelength of UV Light (185 nm). Ambient air is passed over an ultraviolet lamp, which splits some of the molecular oxygen (O_2) in the gas into individual oxygen atoms that attach to other existing oxygen molecules (O_2), forming ozone (O_3).

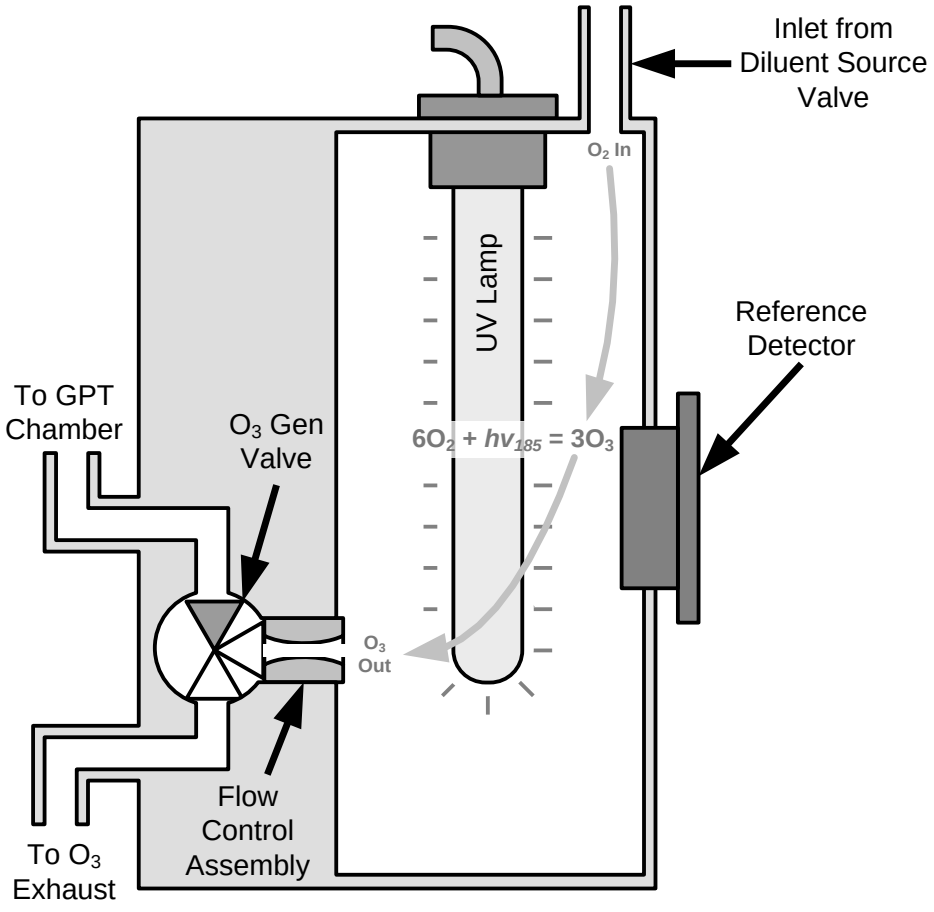


Figure 10-12: O_3 Generator Internal Pneumatics

10.6.2. **O3 GENERATOR – PNEUMATIC OPERATION**

Pneumatic flow through the O_3 generator is created by supplying zero air (diluent) to it under pressure. The zero air source must be capable of maintaining a continuous flow rate of at least 100 cm^3/min unless the optional photometer is also installed, in which case the minimum continuous flow rate must be at least 1.1 LPM.

Input and output gas flow is directed by two valves, both of which must be open:

- The diluent inlet valve: This valve is located on the display/control and input panel and allows diluent / zero air into the calibrator.
- The O_3 generation valve: This valve is located on the body of the O_3 generator downstream from the generator chamber itself and directs the output of the generator to either the GPT mixing chamber or the EXHAUST port of the calibrator.

The rate of flow through the O_3 generator is controlled by a 100 cm^3/min flow control assembly positioned between the O_3 generation chamber and the O_3 generation valve. A self-adjusting pressure regulator on the zero air (diluent) supply gas line maintains the pressure across the critical flow orifice of the flow control assembly (see Section 10.2.1.3).

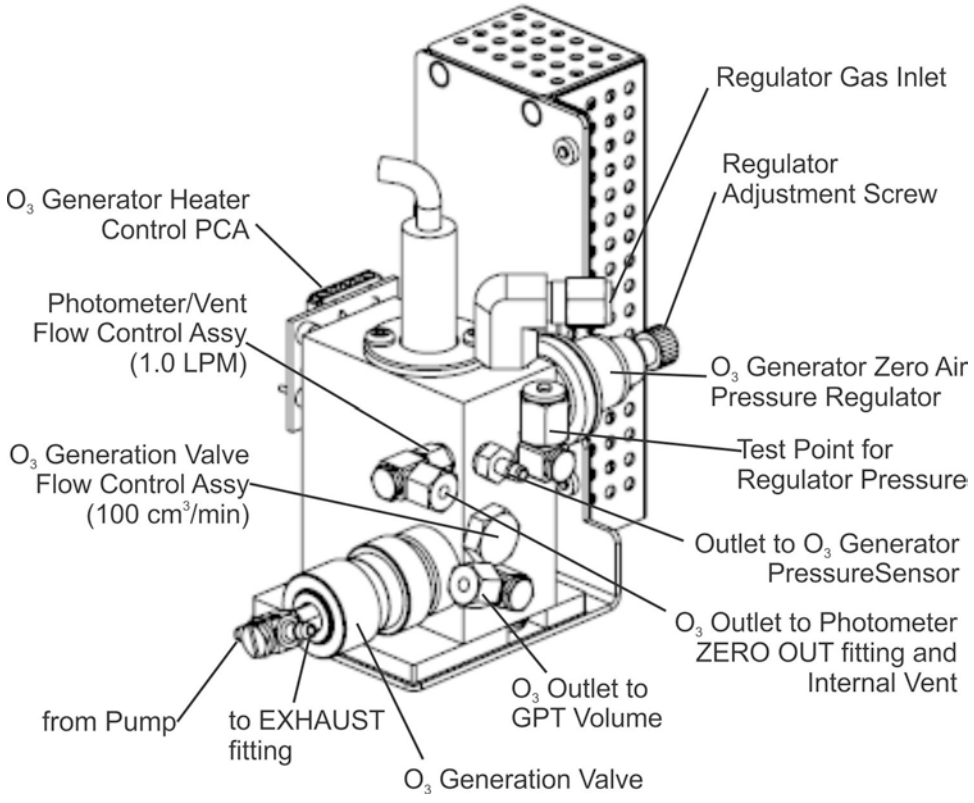


Figure 10-13: O_3 Generator Valve and Gas Fixture Locations

10.6.3. **O3 GENERATOR – ELECTRONIC OPERATION**

Electronically the O_3 generator and its subcomponents act as peripheral devices operated by the CPU via the motherboard. Sensors, such as the UV lamp thermistor, send analog data to the motherboard where it is digitized. Digital data are sent by the motherboard to the calibrator's CPU and where required are stored in either flash memory or on the CPU's Disk-on-Module. Commands from the CPU are sent to the motherboard and forwarded to the various devices via the calibrator's I^2C bus.

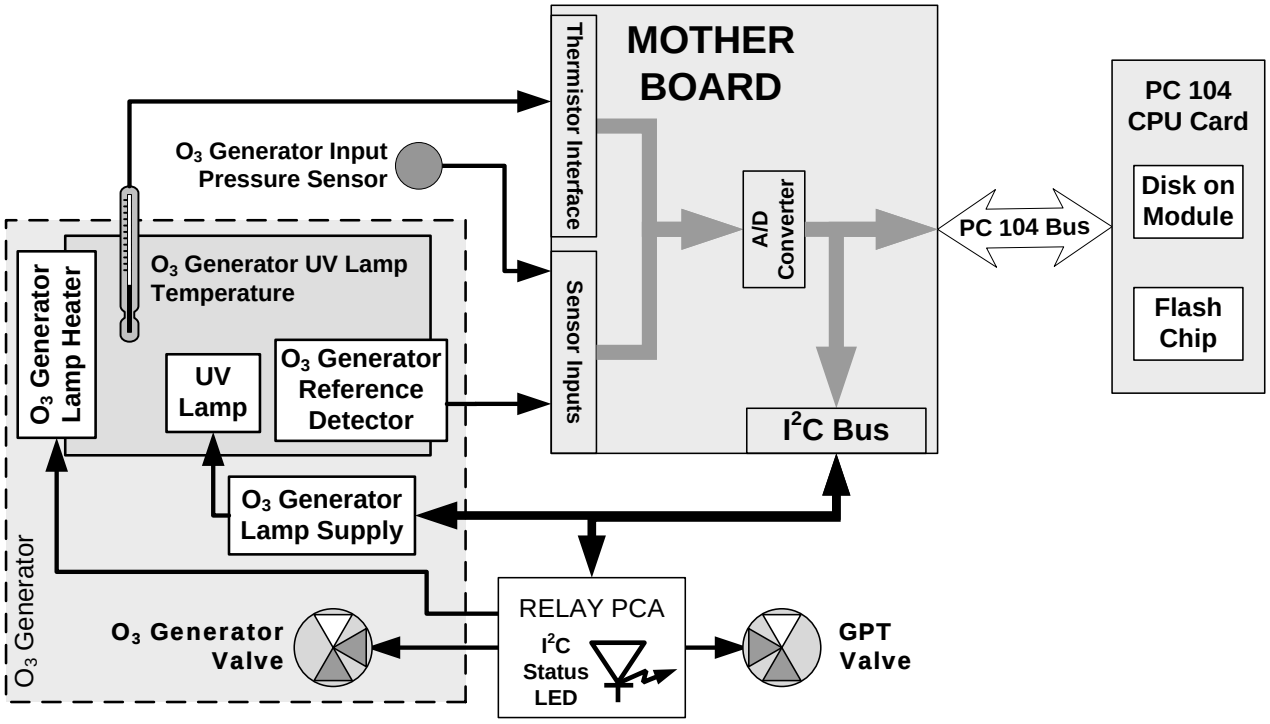


Figure 10-14: O_3 Generator – Electronic Block Diagram

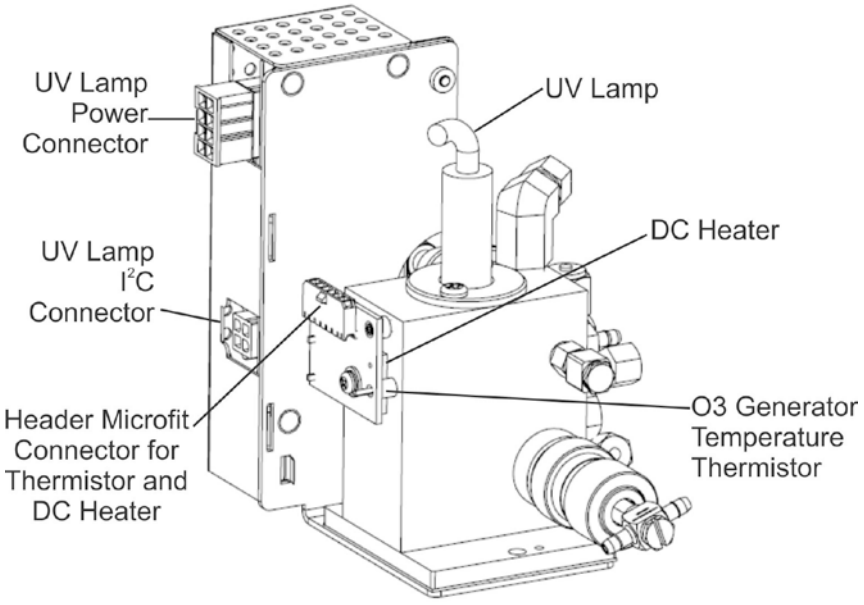


Figure 10-15: O_3 Generator Electronic Components Locations

10.6.3.1. O_3 Generator Temperature Control

In order to operate at peak efficiency the UV lamp of the T750's O_3 generator is maintained at a constant 48ºC. If the lamp temperature falls below 43ºC or rises above 53ºC a warning is issued by the calibrators CPU.

This temperature is controlled as described in the section on the relay PCA (Section 10.3.3). The location of the thermistor and heater associated with the O_3 generator is shown in Figure 10-16:

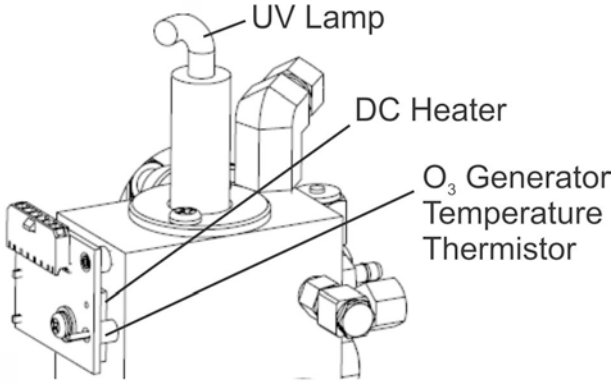


Figure 10-16: O_3 Generator Temperature Thermistor and DC Heater Locations

10.6.3.2. Pneumatic Sensor for the O_3 Generator

A pressure sensor, located on the O_3 generator and photometer, pressure/flow sensor PCA (see Figure 3-4), monitors the output gas pressure of the regulator on the O_3 generator's zero air supply. The regulator is adjusted at the factory to maintain a pressure of 20 PSIG on this line. If the pressure drops below 15 PSIG or rises above 25 PSIG a warning is issued.

10.7. PHOTOMETER OPERATION

The Model T750 calibrator's optional photometer determines the concentration of Ozone (O_3) in a sample gas drawn through it. Sample and calibration gases must be supplied at ambient atmospheric pressure in order to establish a stable gas flow through the absorption tube where the gas' ability to absorb ultraviolet (UV) radiation of a certain wavelength (in this case 254 nm) is measured.

Gas bearing O_3 and zero air are alternately routed through the photometer's absorption tube. Measurements of the UV light passing through the sample gas with and without O_3 present are made and recorded.

Calibration of the photometer is performed in software and does not require physical adjustment. During calibration, the CPU's microprocessor measures the current state of the UV Sensor output and various other physical parameters of the calibrator and stores them in memory. The CPU uses these calibration values, the UV absorption

measurements made on the sample gas in the absorption tube along with data regarding the current temperature and pressure of the gas to calculate a final O_3 concentration.

10.7.1. MEASUREMENT METHOD

10.7.1.1. Calculating O_3 Concentration

The basic principle by which photometer works is called Beer's Law (also referred to as the Beer-Lambert equation). It defines the how light of a specific wavelength is absorbed by a particular gas molecule over a certain distance at a given temperature and pressure. The mathematical relationship between these three parameters for gases at Standard Temperature and Pressure (STP) is:

Equation 10-5

$$I = I_0 e^{-\alpha LC} \quad \text{at STP}$$

Where:

I_o is the intensity of the light if there was no absorption.

I is the intensity with absorption.

L is the absorption path, or the distance the light travels as it is being absorbed.

C is the concentration of the absorbing gas. In the case of the T750, Ozone (O_3).

α is the absorption coefficient that tells how well O_3 absorbs light at the specific wavelength of interest.

To solve this equation for **C**, the concentration of the absorbing Gas (in this case O_3), the application of algebra is required to rearrange the equation as follows:

Equation 10-6

$$C = ln \frac{I_o}{I} \times \frac{1}{\alpha L} \quad \text{at STP}$$

Unfortunately, both ambient temperature and pressure influence the density of the sample gas and therefore the number of ozone molecules present in the absorption tube thus changing the amount of light absorbed.

In order to account for this effect the following addition is made to the equation:

Equation 10-7

$$C = ln \frac{I_o}{I} \times \frac{1}{\alpha L} \times \frac{T}{273^o K} \times \frac{29.92 inHg}{P}$$

Where:

T = sample ambient temperature in degrees Kelvin

P = ambient pressure in inches of mercury

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

Equation 10-8

$$C = ln\ \frac{I_o}{I} \times \frac{10^{9}}{\alpha L} \times \frac{T}{273^{o} K} \times \frac{29.92 inHg}{P}$$

The T750 photometer:

- Measures each of the above variables: ambient temperature; ambient gas pressure; the intensity of the UV light beam with and without O_3 present;
- Inserts know values for the length of the absorption path and the absorption coefficient, and:
- Calculates the concentration of O_3 present in the sample gas.

10.7.1.2. **The Measurement / Reference Cycle**

In order to solve the Beer-Lambert equation, it is necessary to know the intensity of the light passing through the absorption path both when O_3 is present and when it is not. A valve called the measure/reference valve, located on the flow path to the photometer bench, alternates the gas stream flowing to the photometer between zero air (diluent gas) and the O_3 output from the O_3 generator. This cycle takes about 6 seconds. (See Figure 3-4 for physical location; see Figure 10-17 and Figure 10-18 for gas flow diagram of this cycle).

Table 10-2: T750 Photometer Measurement / Reference Cycle

TIME INDEX	STATUS
0 sec.	Measure/Reference Valve Opens to the Measure Path.
0 – 2 sec.	Wait Period. Ensures that the absorption tube has been adequately flushed of any previously present gases.
2 – 3 Seconds	Calibrator measures the average UV light intensity of O_3 bearing Sample Gas (**I**) during this period.
3 sec.	Measure/Reference Valve Opens to the Reference Path.
3 – 5 sec.	Wait Period. Ensures that the absorption tube has been adequately flushed of O_3 bearing gas.
5 – 6 Seconds	Calibrator measures the average UV light intensity of Non-O_3 bearing Sample Gas ($\mathbf{I_0}$) during this period.
CYCLE REPEATS EVERY 6 SECONDS	

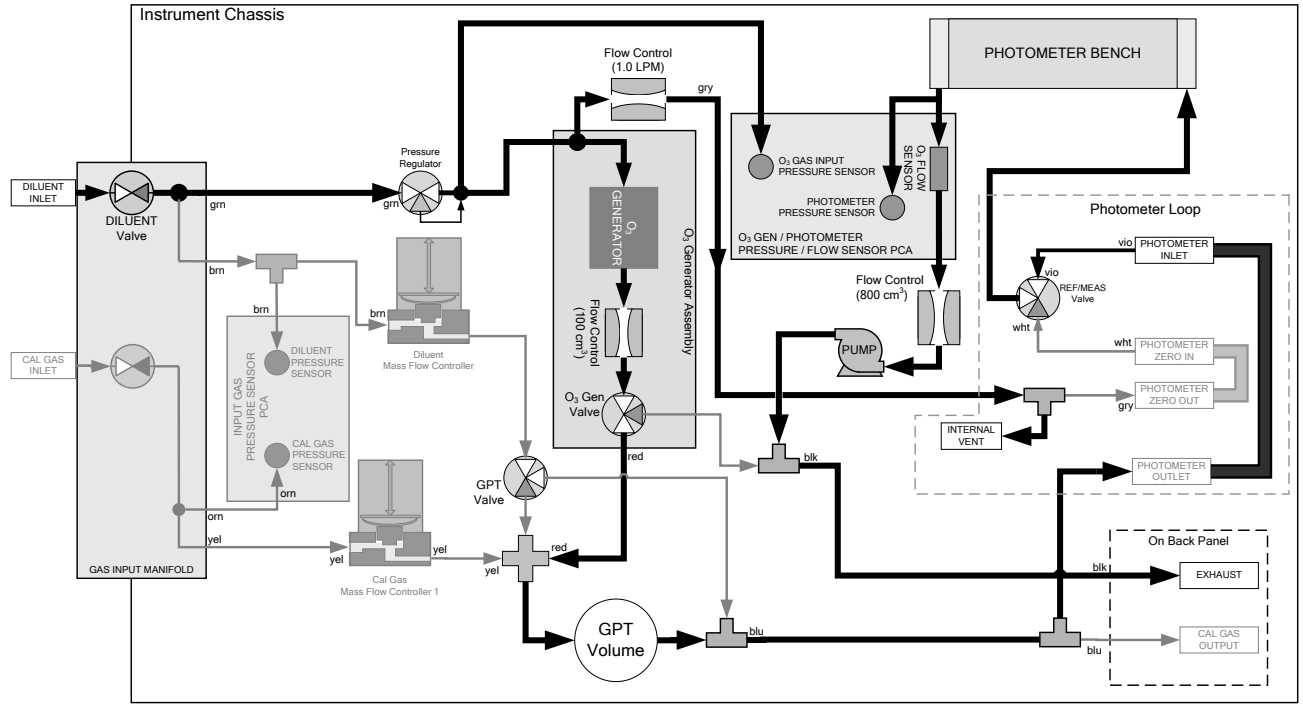


Figure 10-17: O_3 Photometer Gas Flow – Measure Cycle

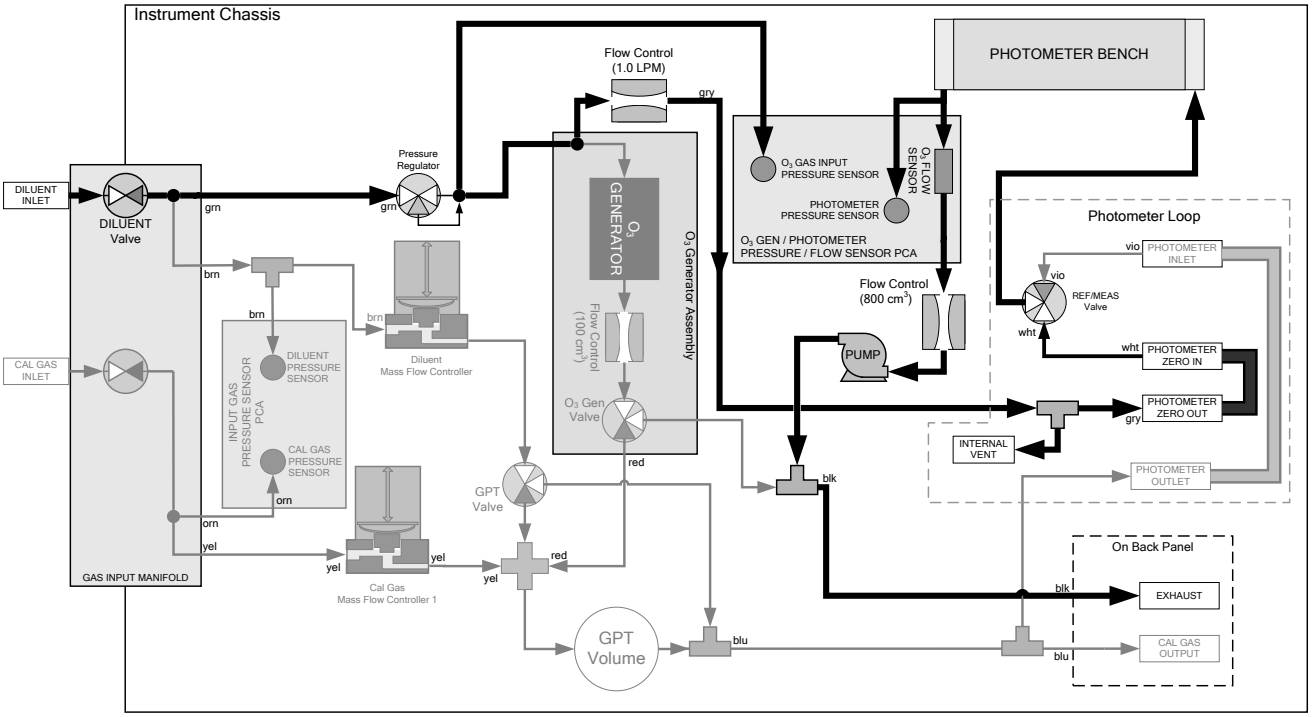


Figure 10-18: O_3 Photometer Gas Flow – Reference Cycle

10.7.1.3. **The Absorption Path**

In the most basic terms, the T750 photometer uses a high energy, mercury vapor lamp to generate a beam of UV light. This beam passes through a window of material specifically chosen to be both non-reactive to O_3 and transparent to UV radiation at 254nm and into an absorption tube filled with sample gas.

Because ozone is a very efficient absorber of UV radiation the absorption path length required to create a measurable decrease in UV intensity is short enough (approximately 42 cm) that the light beam is only required to make one pass through the Absorption Tube. Therefore, no complex mirror system is needed to lengthen the effective path by bouncing the beam back and forth.

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

The detector reacts to the UV light and outputs a current signal that varies in direct relationship with the intensity of the light shining on it. This current signal is amplified and converted to a 0 to 5 VDC voltage analog signal voltage sent to the instrument's motherboard where it is digitized. The CPU to be uses this digital data in computing the concentration of O_3 in the absorption tube.

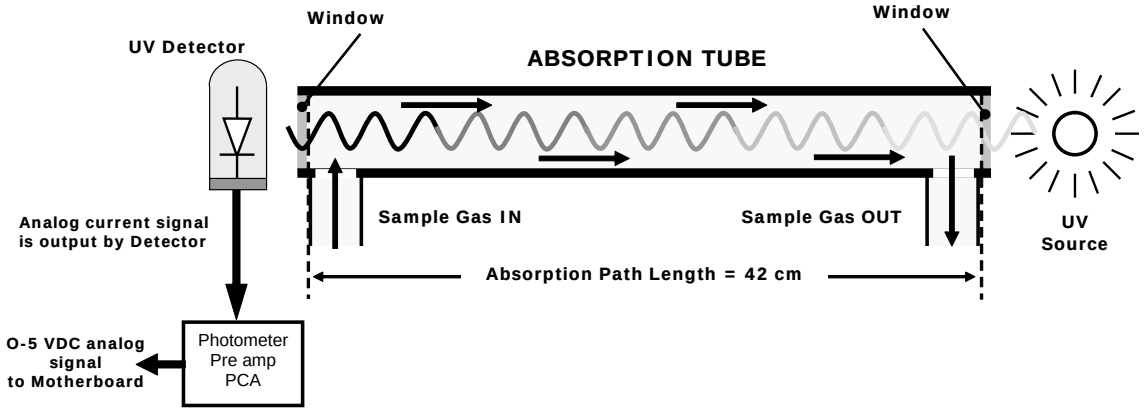


Figure 10-19: O_3 Photometer Absorption Path

10.7.1.4. **Interferent Rejection**

It should be noted that the UV absorption method for detecting ozone is subject to interference from a number of sources. The T750's photometer has been successfully tested for its ability to reject interference from sulfur dioxide, nitrogen dioxide, nitric oxide, water, and meta-xylene.

While the photometer rejects interference from the aromatic hydrocarbon meta-xylene, it should be noted that there are a very large number of volatile aromatic hydrocarbons that could potentially interfere with ozone detection. If the T750 calibrator is installed in an environment where high aromatic hydrocarbon concentrations are suspected, specific tests should be conducted to reveal the amount of interference these compounds may be causing.

10.7.2. **PHOTOMETER LAYOUT**

The photometer is where the absorption of UV light by ozone is measured and converted into a voltage. It consists of several sub-assemblies:

- A mercury-vapor UV lamp. This lamp is coated in a material that optically screens the UV radiation output to remove the O_3 producing 185nm radiation. Only light at 254nm is emitted.
- An AC power supply to supply the current for starting and maintaining the plasma arc of the mercury vapor lamp.
- A thermistor and DC heater attached to the UV Lamp to maintain the Lamp at an optimum operating temperature.
- 42 cm long quartz absorption tube.
- A thermistor attached to the quartz tube for measuring sample gas temperature.
- Gas inlet and outlet mounting blocks that route sample gas into and out of the photometer.
- The vacuum diode, UV detector that converts UV light to a DC current.
- A preamplifier assembly, which converts the Detector's current output into a DC voltage, then amplifies it to a level readable by the A-to-D converter circuitry of the instrument's motherboard.

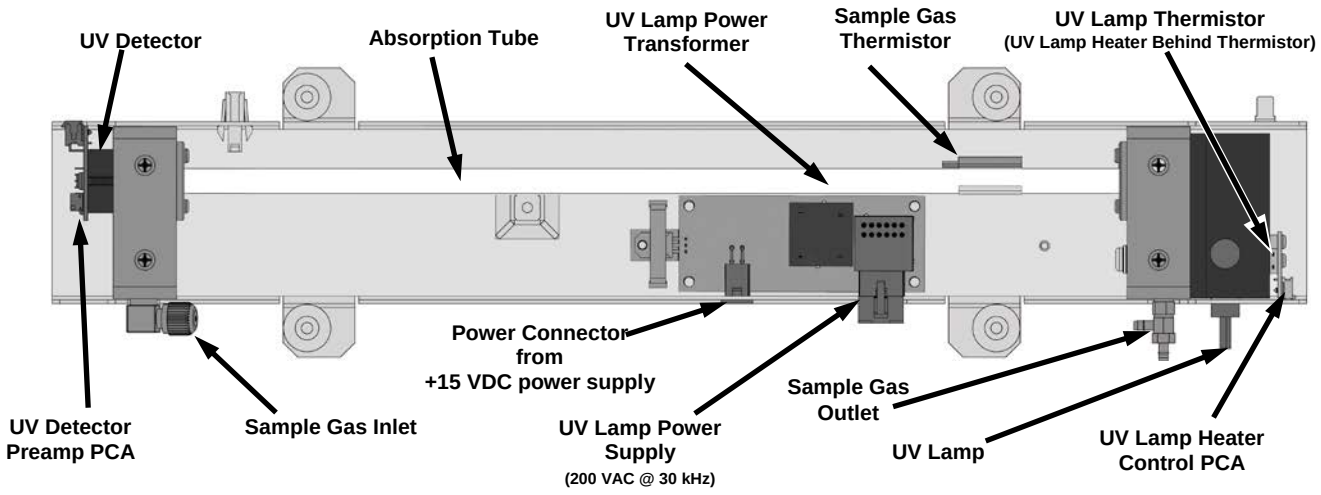


Figure 10-20: O_3 Photometer Layout – Top Cover Removed

10.7.3. **PHOTOMETER PNEUMATIC OPERATION**

The flow of gas through the photometer is created by an internal pump that pulls air though the instrument. There are several advantages to this "pull through" configuration. Placing the pump downstream from the absorption tube avoids problems caused by the pumping process heating and compressing the sample.

In order to measure the presence of low concentrations of O_3 in the sample air, it is necessary to establish and maintain a relatively constant and stable volumetric flow of sample gas through the photometer. The simplest way to accomplish this is by placing a

flow control assembly containing a critical flow orifice directly upstream of the pump but downstream from the absorption tube.

The critical flow orifice installed in the pump supply line is tuned to create a flow of 800 cm^3/min. A pressure sensor and a flow sensor, located on the O_3 generator/photometer pressure flow sensor PCA, monitor the pressure and flow rate of the gas passing through the photometers absorption tube.

See for depictions of the airflow related to the photometer.

10.7.4. PHOTOMETER ELECTRONIC OPERATION

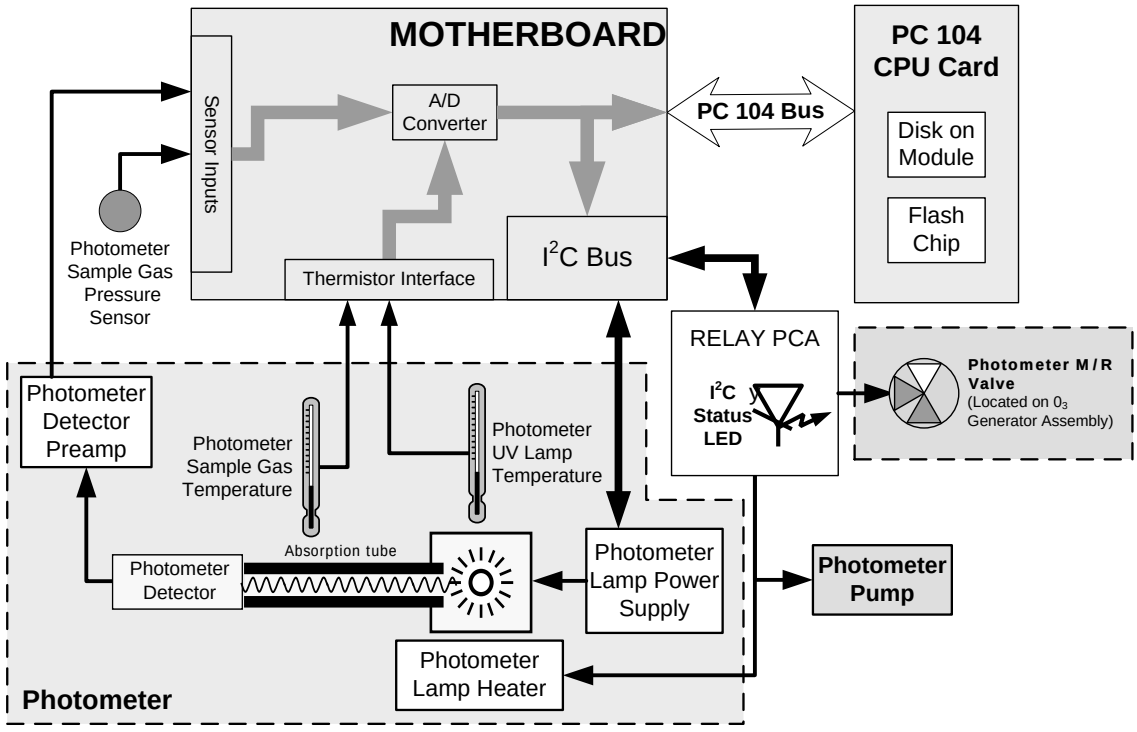


Figure 10-21: O_3 Photometer Electronic Block Diagram

Like the O_3 generator, the O_3 photometer and its subcomponents act as peripheral devices operated by the CPU via the motherboard. Communications to and from the CPU are handled by the motherboard.

Outgoing commands for the various devices such as the photometer pump, the UV lamp power supply, or the UV Lamp heater are issued via the I^2C bus to circuitry on the relay PCA that turns them ON/OFF. The CPU also issues commands over the I^2C bus that cause the relay PCA to cycle the measure/reference valve back and forth.

Incoming data from the UV light detector is amplified locally then converted to digital information by the motherboard. Output from the photometers temperature sensors is also amplified and converted to digital data by the motherboard. The O_3 concentration of the sample gas is computed by the CPU using this data (along with gas pressure and flow data received from the T750's pressure sensors).

10.7.4.1. O_3 Photometer Temperature Control

In order to operate at peak efficiency the UV lamp of the T750's O_3 photometer is maintained at a constant 58ºC. This is intentionally set at a temperature higher than the ambient temperature of the T750's operating environment to ensure that local changes in temperature do not affect the UV Lamp. If the lamp temperature falls below 56ºC or rises above 61ºC a warning is issued by the calibrators CPU.

This temperature is controlled as described in the section on the relay PCA (Section 10.3.3.2).

The following TEST functions report these temperatures and are viewable from the instrument's LCD touchscreen:

- **PHOTOLTEMP** - The temperature of the UV Lamp reported in ºC.
- **PHOTOSTEMP** - The temperature of the Sample gas in the absorption tube reported in ºC.

10.7.4.2. Pneumatic Sensors for the O_3 Photometer

The sensors located on the pneumatic sensor just to the left rear of the O_3 generator assembly measure the absolute pressure and the flow rate of gas inside the photometer's absorption tube. This information is used by the CPU to calculate the O_3 concentration of the sample gas (See Equation 10-7). Both of these measurements are made downstream from the absorption tube but upstream of the pump. A critical flow orifice located between the flow sensor and the pump maintains the gas flow through the photometer at 800 cm^3/min.

The following TEST functions are viewable from the instrument's LCD touchscreen display:

- **PHOTOFLOW** - The flow rate of gas through the photometer measured in LPM.
- **PHOTOSPRESS** – the pressure of the gas inside the absorption tube. This pressure is reported in inches of mercury-absolute (**in-Hg-A**), i.e. referenced to a vacuum (zero absolute pressure). This is not the same as **PSIG.**

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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	*Assembly*
CAS	*Code-Activated Switch*
CD	*Corona Discharge*, 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	*Converter Efficiency*, the percentage of light energy that is actually converted into electricity
CEM	*Continuous Emission Monitoring*
Chemical formulas that may be included in this document:	
CO2	carbon dioxide
C3H8	propane
CH4	methane
H2O	water vapor
HC	general abbreviation for hydrocarbon
HNO3	nitric acid
H2S	hydrogen sulfide
NO	nitric oxide
NO2	nitrogen dioxide
NOX	nitrogen oxides, here defined as the sum of NO and NO2
NOy	nitrogen oxides, often called odd nitrogen: the sum of NOX plus other compounds such as HNO3 (definitions vary widely and may include nitrate (NO3), PAN, N2O and other compounds as well)
NH3	ammonia
O2	molecular oxygen
O3	ozone

Term	Description/Definition
SO2	sulfur dioxide
cm^3	metric abbreviation for *cubic centimeter* (replaces the obsolete abbreviation "cc")
CPU	*Central Processing Unit*
DAC	*Digital-to-Analog Converter*
DAS	*Data Acquisition System*
DCE	*Data Communication Equipment*
DFU	*Dry Filter Unit*
DHCP	*Dynamic Host Configuration Protocol.* 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	*Diagnostics*, the diagnostic settings of the instrument
DOM	*Disk On Module,* a 44-pin IDE flash drive with up to 256MB storage capacity for instrument's firmware, configuration settings and data
DOS	*Disk Operating System*
DRAM	*Dynamic Random Access Memory*
DR-DOS	*Digital Research DOS*
DTE	*Data Terminal Equipment*
EEPROM	*Electrically Erasable Programmable Read-Only Memory* also referred to as a FLASH chip or drive
ESD	*Electro-Static Discharge*
ETEST	*Electrical Test*
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	*Fluorinated Ethylene Propylene* polymer, one of the polymers that Du Pont markets as *Teflon*®
Flash	non-volatile, solid-state memory
FPI	*Fabry-Perot Interface*: a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	*Gas Filter Correlation*
I^2C bus	a clocked, bi-directional, serial bus for communication between individual instrument components
IC	*Integrated Circuit*, 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

Term	Description/Definition
IP	*Internet Protocol*
IZS	*Internal Zero Span*
LAN	*Local Area Network*
LCD	*Liquid Crystal Display*
LED	*Light Emitting Diode*
LPM	*Liters Per Minute*
MFC	*Mass Flow Controller*
M/R	*Measure/Reference*
MOLAR MASS	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. 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. Atomic weights can be found on any Periodic Table of Elements.
NDIR	*Non-Dispersive Infrared*
NIST-SRM	*National Institute of Standards and Technology - Standard Reference Material*
PC	*Personal Computer*
PCA	P*rinted Circuit Assembly*, the PCB with electronic components, ready to use
PC/AT	*Personal Computer / Advanced Technology*
PCB	*Printed Circuit Board*, the bare board without electronic component
PFA	*Per-Fluoro-Alkoxy*, an inert polymer; one of the polymers that *Du Pont* markets as *Teflon*®
PLC	*Programmable Logic Controller*, a device that is used to control instruments based on a logic level signal coming from the instrument
PLD	*Programmable Logic Device*
PLL	*Phase Lock Loop*
PMT	*Photo Multiplier Tube*, a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	*Part Number*
PSD	*Prevention of Significant Deterioration*
PTFE	*Poly-Tetra-Fluoro-Ethylene*, a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that *Du Pont* markets as

Term	Description/Definition
	Teflon®
PVC	*Poly Vinyl Chloride*, 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	*Storage and Retrieval of Aerometric Data*
SLAMS	*State and Local Air Monitoring Network Plan*
SLPM	*Standard Liters Per Minute* of a gas at standard temperature and pressure
STP	*Standard Temperature and Pressure*
TCP/IP	*Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices
TEC	*Thermal Electric Cooler*
TPC	*Temperature/Pressure Compensation*
USB	*Universal Serial Bus*: 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	*Variables*, the variable settings of the instrument
V-F	*Voltage-to-Frequency*
Z/S	*Zero / Span*

APPENDIX A –Software Documentation, T700, T750, 700E

Software Versions: T-Series 1.1.7; E-Series 7.0.4

APPENDIX A-1: Software Menu Trees

APPENDIX A-2: Setup Variables for Serial I/O

APPENDIX A-3: Warnings and Test Functions

APPENDIX A-4: Signal I/O Definitions

APPENDIX A-5: MODBUS Register Map

APPENDIX A-6: Terminal Command Designators

APPENDIX A-1: Software Menu Trees

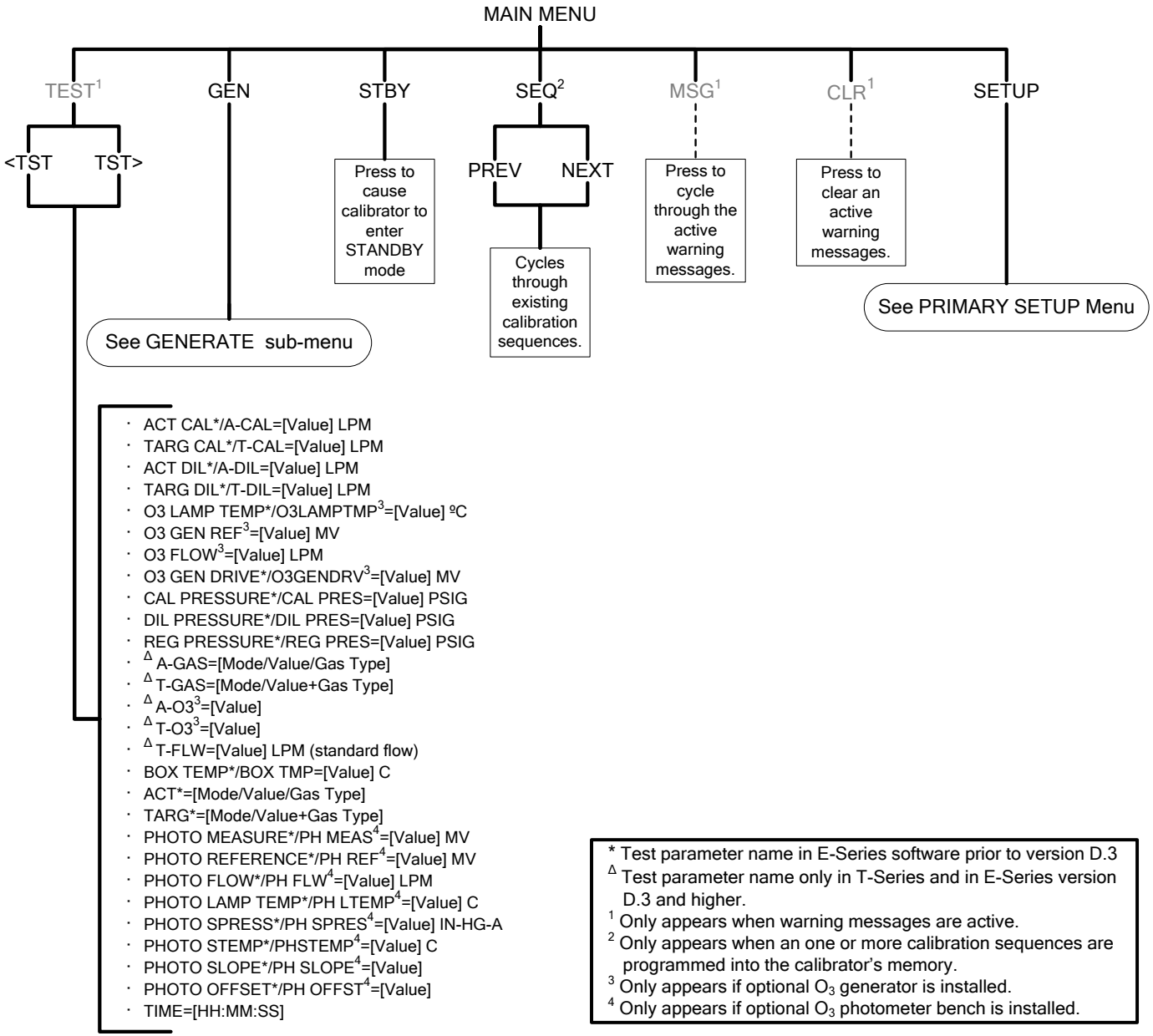

Figure A-1a: T700 and 700E Main Menu

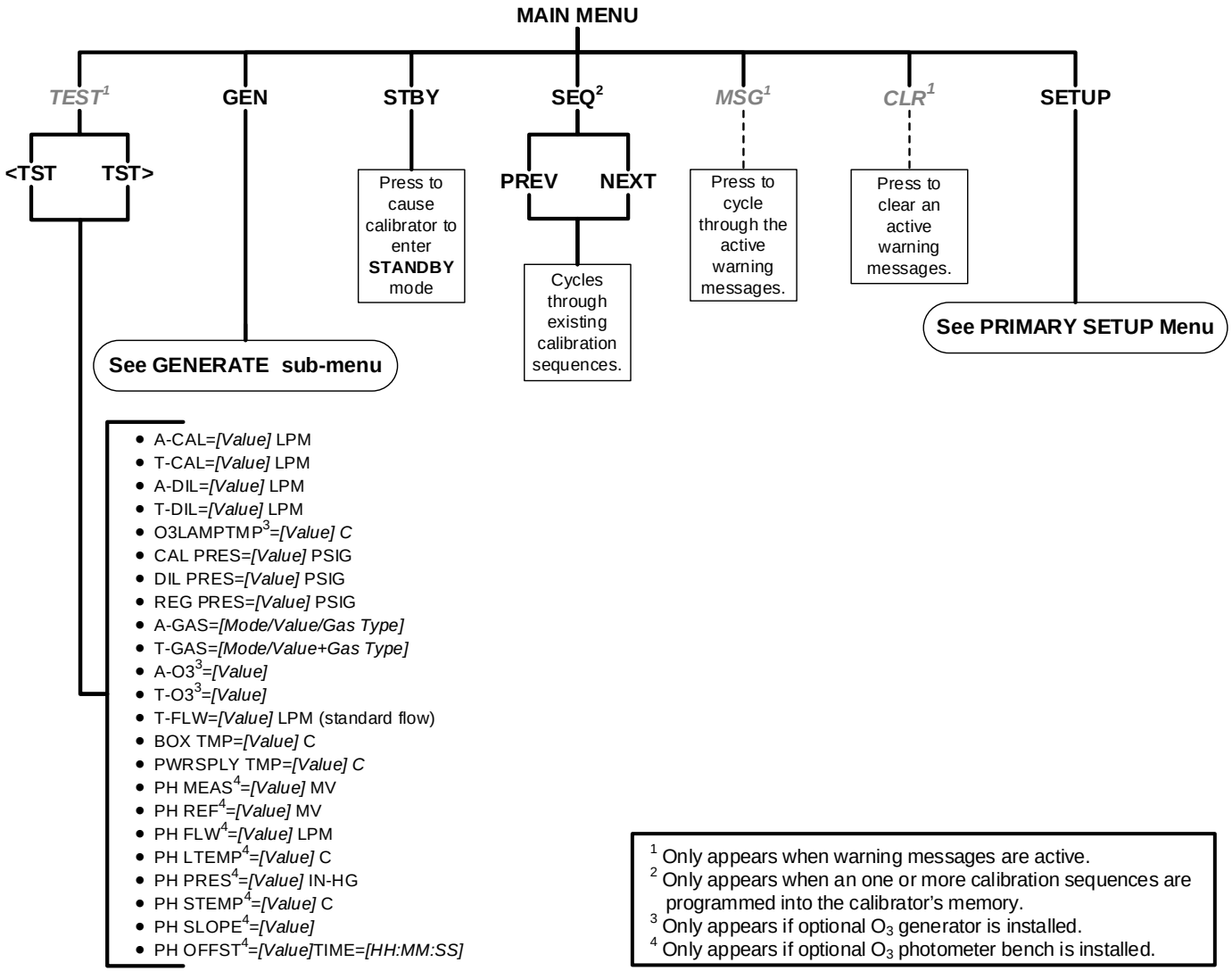

Figure A-1b: T750 Main Menu

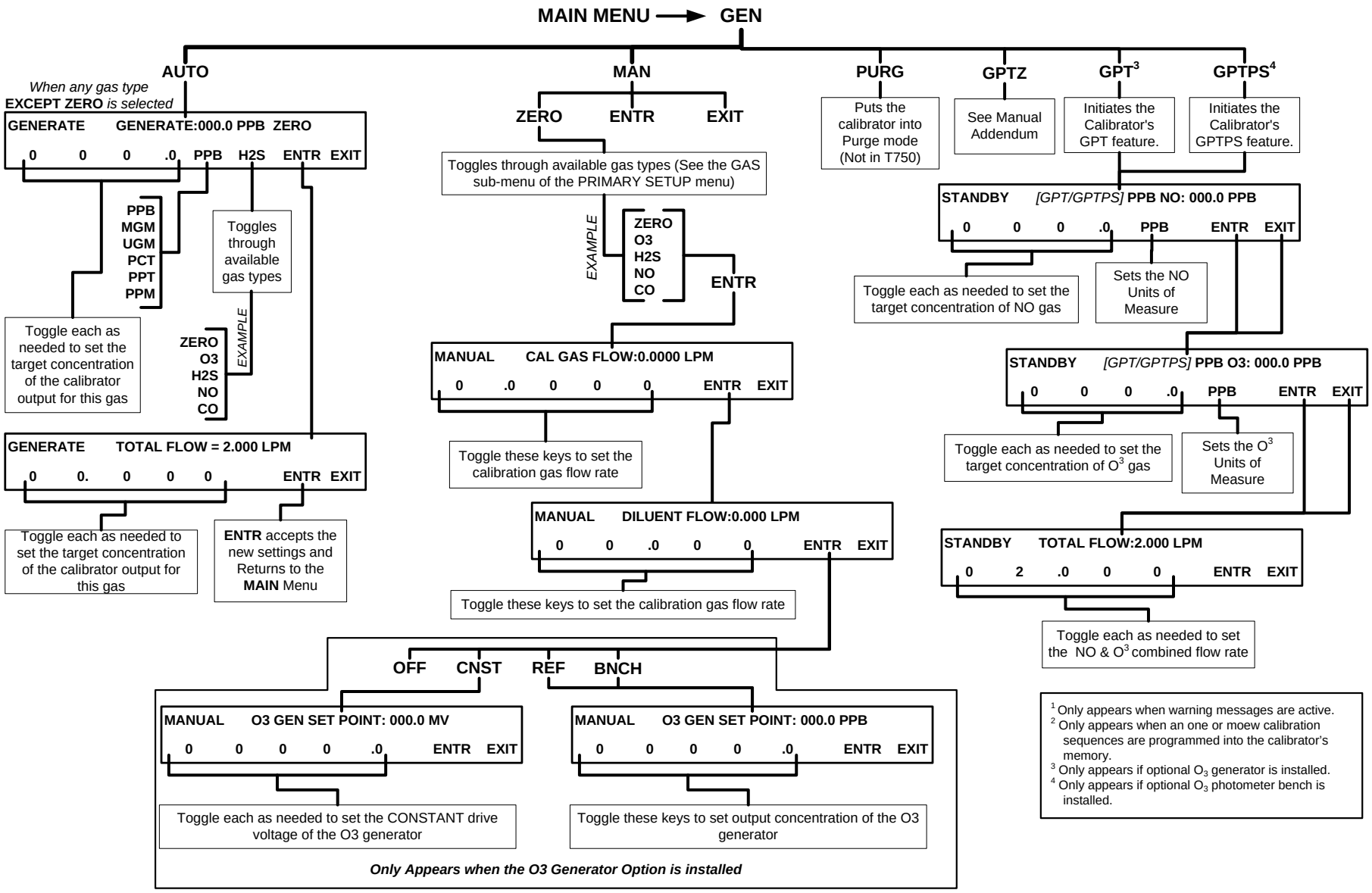

Figure A-2: Main Menu – GEN (GENERATE) Submenu

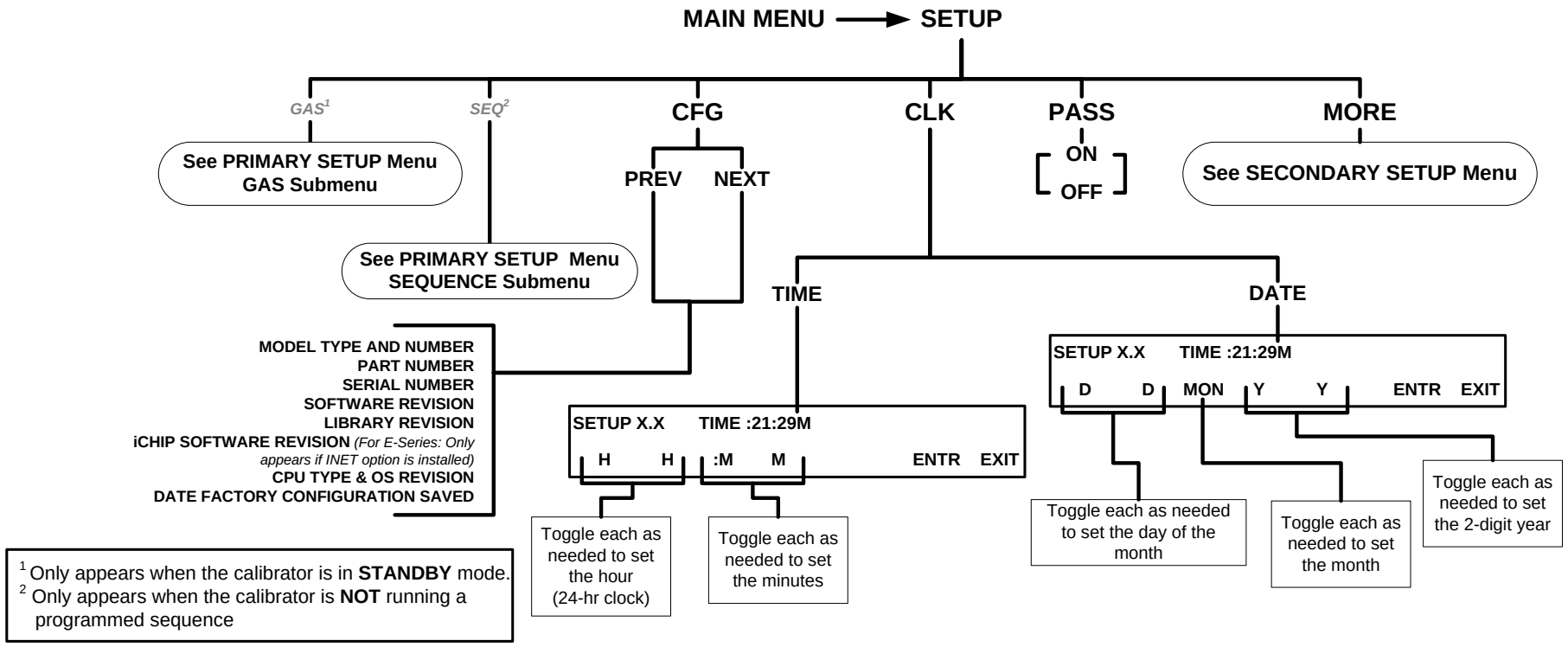

Figure A-3: PRIMARY SETUP MENU - Basics

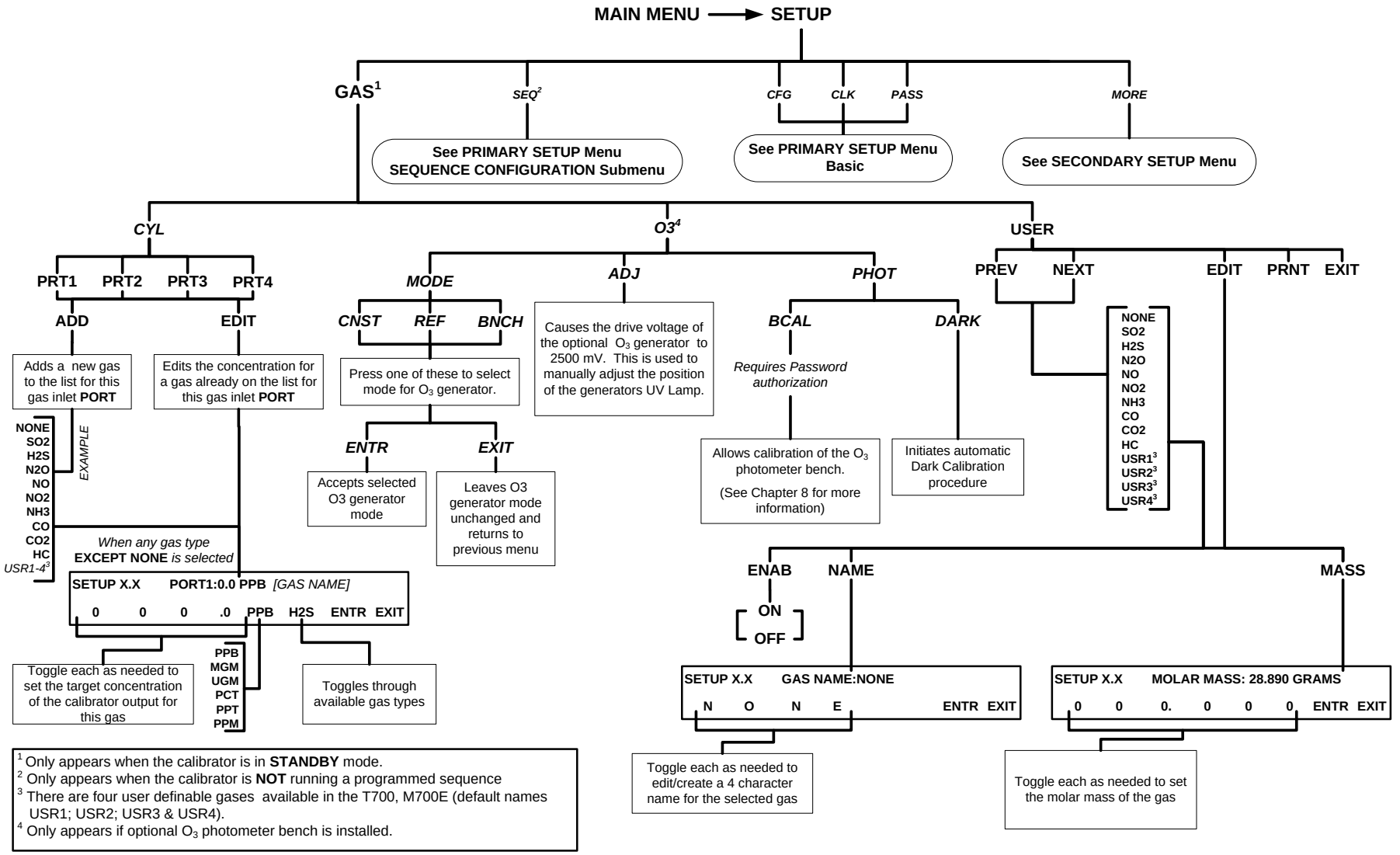

Figure A-4: PRIMARY SETUP Menu - GAS Submenu

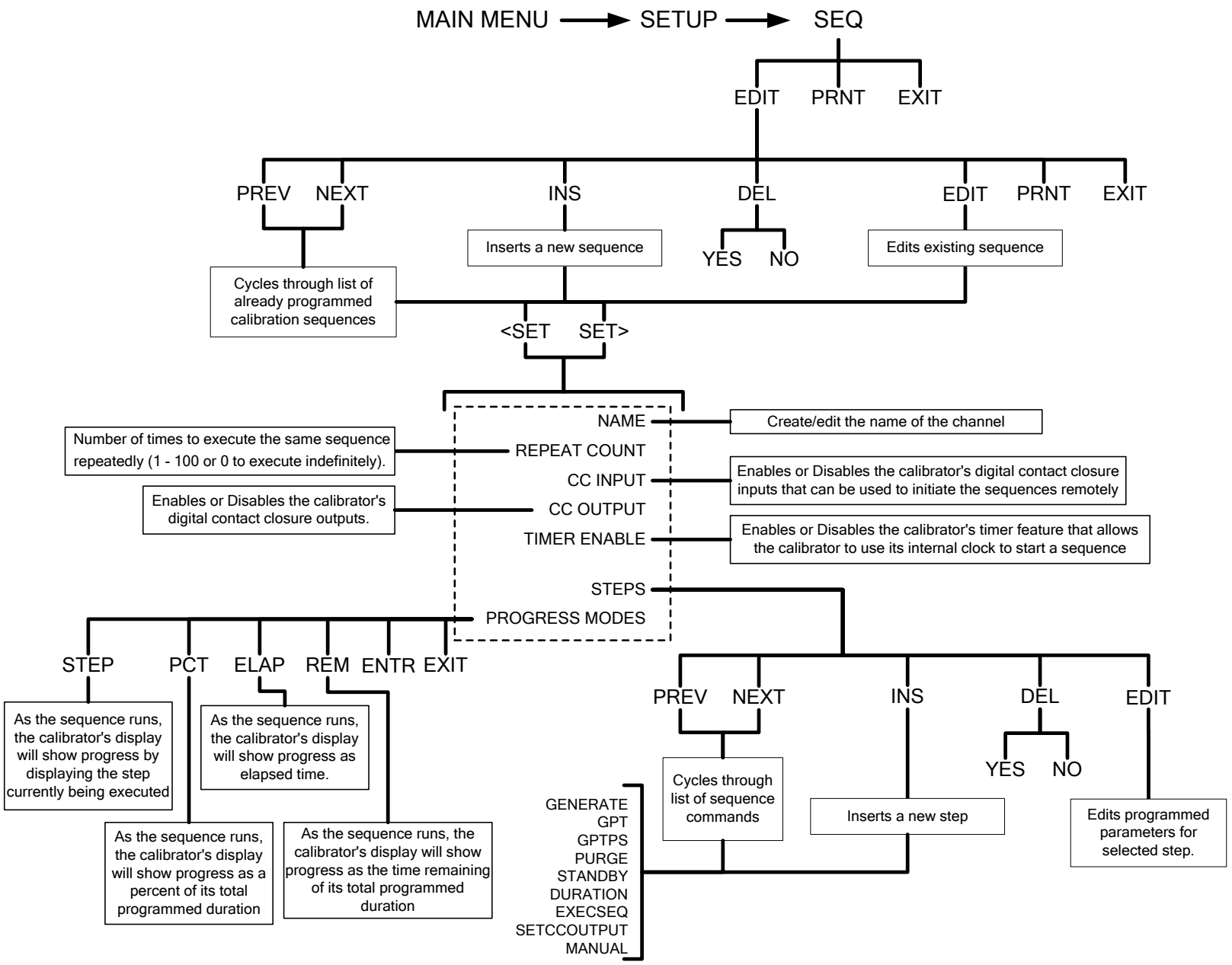

Figure A-5: PRIMARY SETUP Menu - SEQUENCE CONFIGURATION Submenu

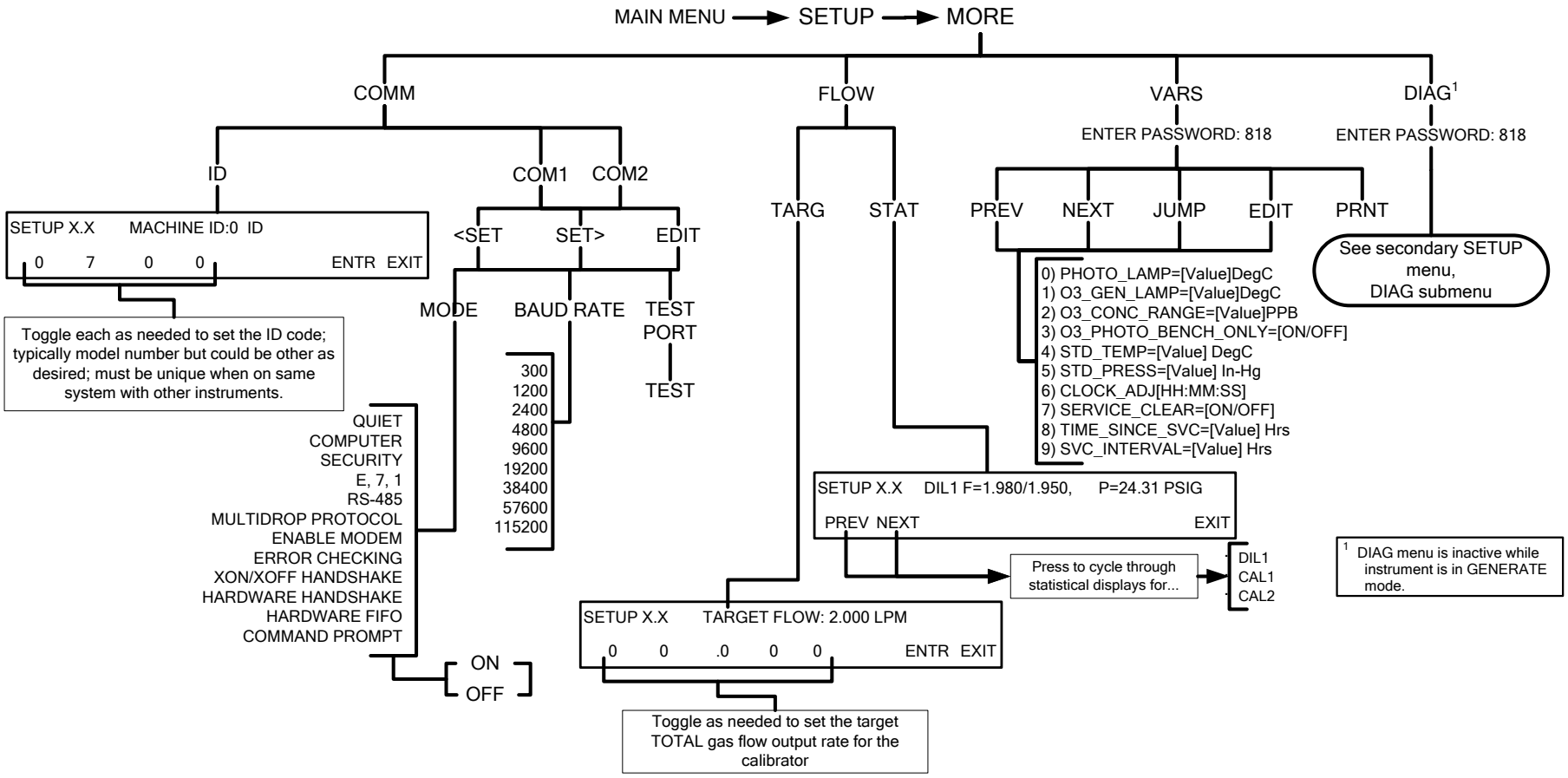

Figure A-6: SECONDARY SETUP Menu - Basic

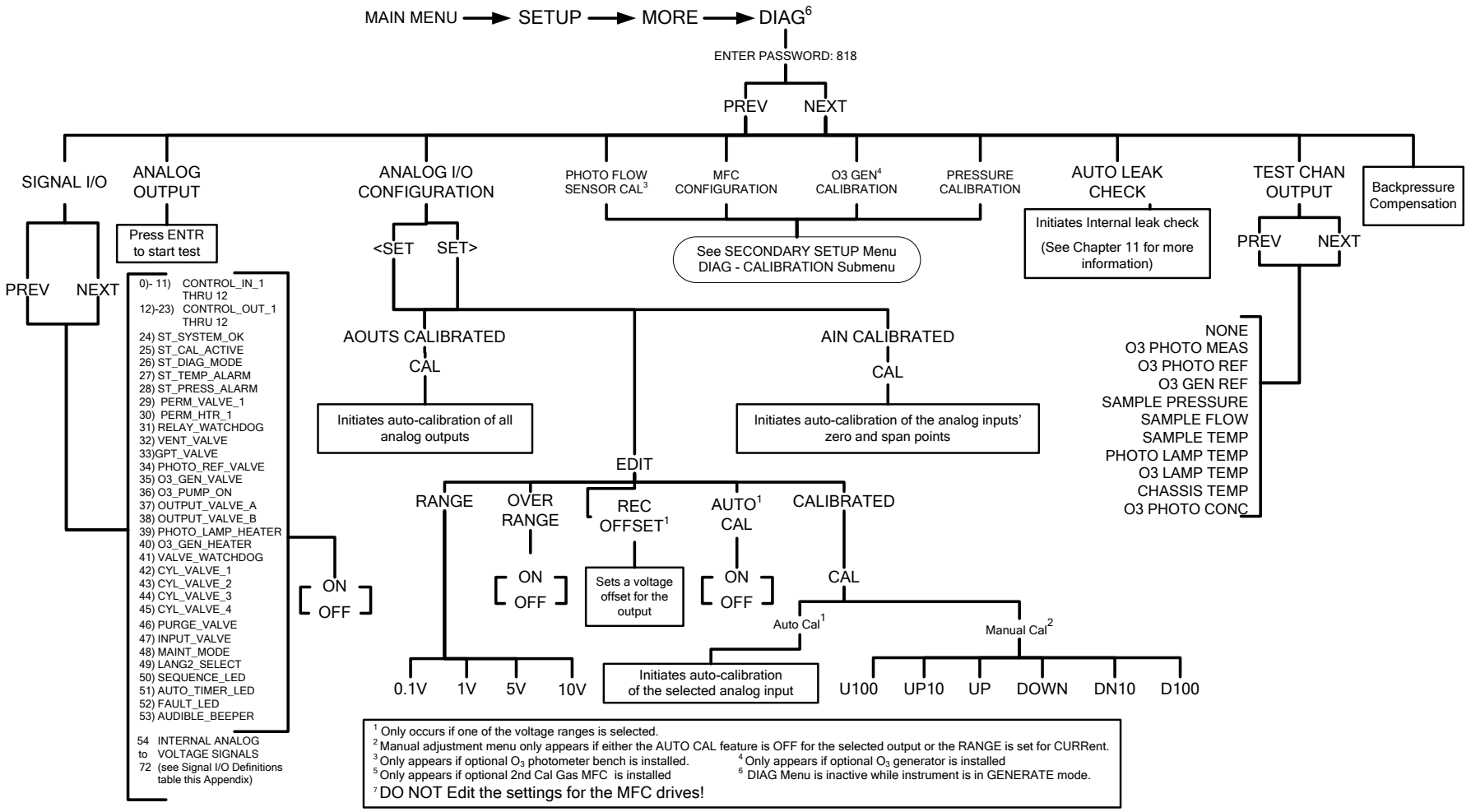

Figure A-7a: T700, 700E SECONDARY SETUP Menu - DIAG Submenu

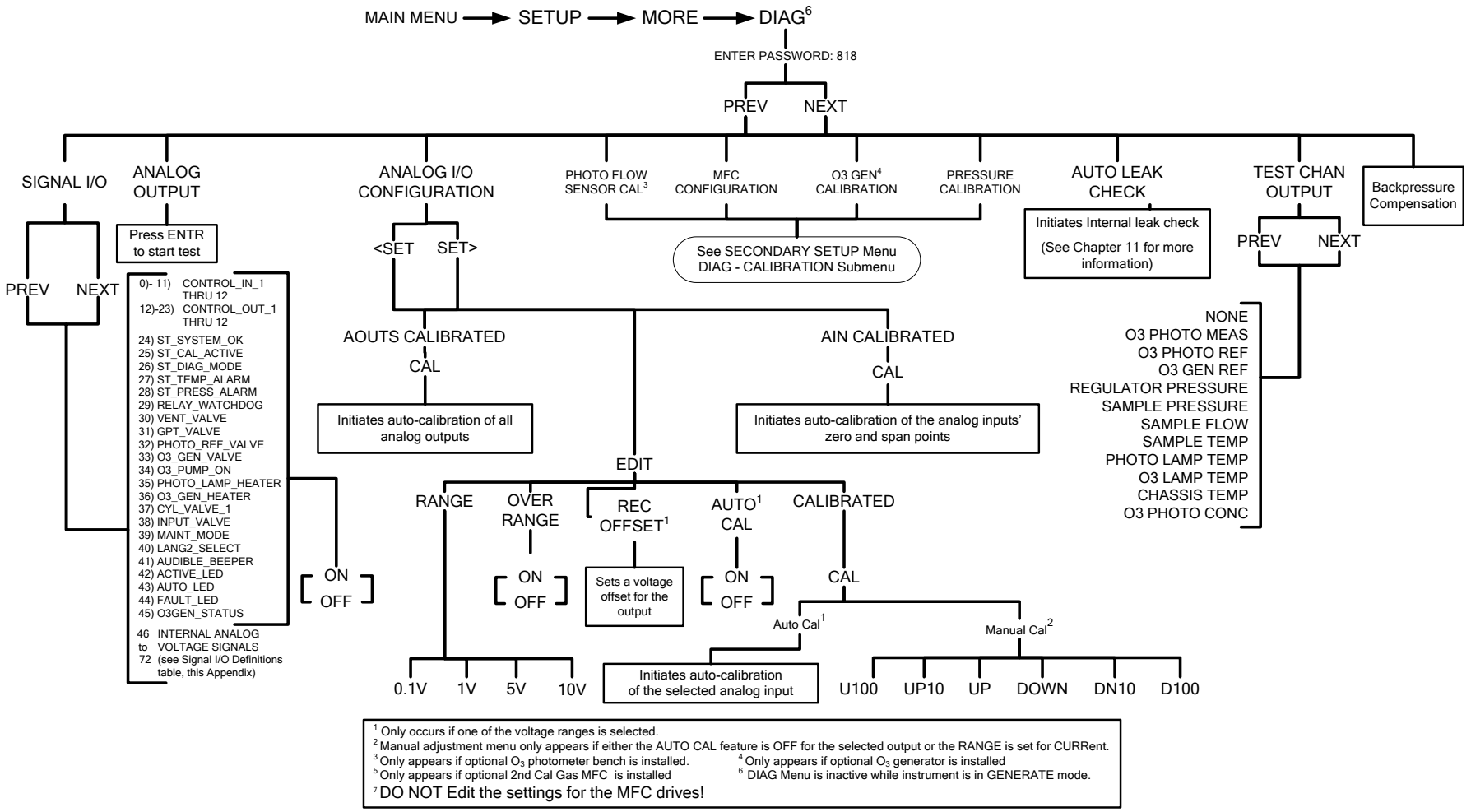

Figure A-7b: T750 SECONDARY SETUP Menu - DIAG Submenu

APPENDIX A-2: Setup Variables for Serial I/O

Table A-1: Setup Variables

Setup Variable	Numeric Units	Default Value	Value Range	Description
Low Access Level Setup Variables (818 password)				
PHOTO_LAMP	ºC	58 Warnings: 56–61	0–100	Photometer lamp temperature set point and warning limits.
O3_GEN_LAMP	ºC	48 Warnings: 43–53	0–100	O_3 generator lamp temperature set point and warning limits.
O3_CONC_RANGE	PPB	500	0.1–20000	O_3 concentration range for test channel analog output.
O3_PHOTO_BENCH_ONLY	—	ON	OFF, ON	O_3 bench control flag. ON turns on pump and switches measure/reference valve only in bench generation mode.
STD_TEMP	ºC	25	0–100	Standard temperature for unit conversions.
STD_PRESS	"Hg	29.92	15–50	Standard pressure for unit conversions.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
SERVICE_CLEAR	—	OFF	OFF ON	ON resets the service interval timer.
TIME_SINCE_SVC	Hours	0	0–500000	Time since last service.
SVC_INTERVAL	Hours	0	0–100000	Sets the interval between service reminders.
DRYER_CLEAR [1]	—	OFF	OFF ON	ON resets the dryer service interval timer.

[1] 700H only

APPENDIX A-3: Warnings and Test Functions

Table A-2: Warning Messages

Name [1]	Message Text	Description
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WPHOTOLTEMP	PHOTO LAMP TEMP WARNING	Photometer lamp temperature outside of warning limits.
WO3GENTEMP	O3 GEN LAMP TEMP WARNING	O_3 generator lamp temperature outside of warning limits.
WPERMTEMP1 [2]	PERM TUBE #1 TEMP WARNING	Permeation tube #1 temperature outside of warning limits.
WPERMTEMP2 [3]	PERM TUBE #2 TEMP WARNING	Permeation tube #2 temperature outside of warning limits.
WPHOTOREF	PHOTO REFERENCE WARNING	Photometer reference reading less than 2500 mV or greater than 4999 mV.
WLAMPSTABIL	PHOTO LAMP STABILITY WARNING	Photometer lamp reference step changes occur more than 25% of the time.
WO3GENREF	O3 GEN REFERENCE WARNING	O_3 reference detector drops below 5 mV during reference feedback O_3 generator control.
WREGPRESS	REGULATOR PRESSURE WARNING	Regulator pressure outside of warning limits.
WMFCPRESS	MFC PRESSURE WARNING	Any MFC pressure outside of warning limits.
WMFCFLOW	MFC FLOW WARNING	Any MFC drive less than 10% of full scale or greater than full scale.
WMFCCAL	MFC CALIBRATION WARNING	Any MFC sensor offset greater than allowable limit.
WO3PUMP	O3 PUMP WARNING	O_3 pump failed to turn on within timeout period.
WOUTPUT	INVALID OUTPUT WARNING	An invalid output has been selected for the requested gas generation. For example, output B was selected when generating ozone.
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.
WVALVEBOARD	VALVE BOARD WARN	Firmware is unable to communicate with the valve board.
WLAMPDRIVER	LAMP DRIVER WARN	Firmware is unable to communicate with either the O_3 generator or photometer lamp I^2C driver chip.
WFRONTPANEL [4]	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WMFCCOMM [5]	MFC COMMUNICATION WARNING	Firmware is unable to communicate with any MFC.

Name [1]	Message Text	Description
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.
WPWRSPLYTEMP [6]	PWR SPLY TEMP WARN	Power supply temperature has exceeded range limits.

[1] The name is used to request a message via the RS-232 interface, as in “T BOXTEMP”

[2] Permeation tube option

[3] Dual permeation tube option

[4] E-Series only

[5] I^2C MFC

[6] T750 only

Table A-3: Test Functions

Name [1]	Message Text	Description
ACTCALFLOW	ACT CAL=0.0800 LPM	Actual cal gas flow rate.
TARGCALFLOW	TARG CAL=0.0000 LPM	Target cal gas flow rate.
ACTDILFLOW	ACT DIL=1.920 LPM	Actual diluent flow rate.
TARGDILFLOW	TARG DIL=0.000 LPM	Target diluent flow rate.
O3GENFRAC [2]	O3 GEN FRAC=0.50	O_3 generator operating flow fraction.
O3GENREF	O3 GEN REF=1000.0 MV	O_3 generator reference detector reading.
O3GENFLOW	O3 FLOW=0.1050 LPM	O_3 generator flow rate.
O3GENDRIVE	O3 GEN DRIVE=800.0 MV	O_3 generator lamp drive output.
O3GENTEMP	O3 LAMP TEMP=49.7 C	O_3 generator lamp temperature.
CALPRESS	CAL PRESSURE=25.1 PSIG	Cal gas pressure.
DILPRESS	DIL PRESSURE=25.1 PSIG	Diluent pressure.
REGPRESS	REG PRESSURE=20.1 PSIG	Regulator pressure.
ACTCONC	ACT=GENERATE 37 PPB O3	Actual concentration being generated, computed from real-time inputs.
TARGCONC	TAR=GENERATE 100 PPB O3	Target concentration to generate.
BOXTEMP	BOX TEMP=31.2 C	Internal chassis temperature.
PERMTEMP1 [3]	PERM TUBE #1 TEMP=50.4 C	Permeation tube #1 temperature.
PERMTEMP2 [4]	PERM TUBE #2 TEMP=50.4 C	Permeation tube #2 temperature.
PERMFLOW [3]	PERM FLOW=0.1050 LPM	Permeation tube flow rate. This is a property of the permeation tube (SETUP-GAS-PERM). Its value depends on which permeation tube is in use.
PHOTOMEAS	PHOTO MEASURE=2998.8 MV	Photometer detector measure reading.
PHOTOREF	PHOTO REFERENCE=3000.0 MV	Photometer detector reference reading.
PHOTOFLOW	PHOTO FLOW=0.2978 LPM	Photometer sample flow rate.
PHOTOLTEMP	PHOTO LAMP TEMP=52.6 C	Photometer lamp temperature.
PHOTOSPRESS	PHOTO SPRESS=29.9 IN-HG-A	Photometer sample pressure.
PHOTOSTEMP	PHOTO STEMP=31.8 C	Photometer sample temperature.
PHOTOSLOPE	PHOTO SLOPE=1.000	Photometer slope computed during zero/span bench calibration.
PHOTOOFFSET	PHOTO OFFSET=0.0 PPB	Photometer offset computed during zero/span bench calibration.

PHOTOSTABIL [5]	PHOTO STABIL=0.1 PPB	Photometer concentration stability (standard deviation of 25 bench concentration samples taken 10 seconds apart).
TESTCHAN	TEST=2753.9 MV	Value output to TEST_OUTPUT analog output, selected with TEST_CHAN_ID variable.
CLOCKTIME	TIME=14:48:01	Current instrument time of day clock.
PWRSPLYTEMP [6]	PWRSPLY TMP=25.0 C	Power supply temperature.

[1] The name is used to request a message via the RS-232 interface, as in “T BOXTEMP”
[2] Low range option
[3] Permeation tube option
[4] Dual permeation tube option
[5] O_3 photometer stability measurement option
[6] T750 only

APPENDIX A-4: Signal I/O Definitions

Table A-4: Signal I/O Definitions

Signal Name	Bit or Channel Number	Description
U11, J1004, control inputs, pins 1-6 = bits 0-5, read, default I/O address 321 hex		
CONTROL_IN_1 – CONTROL_IN_6	0–5	0 = input asserted 1 = de-asserted
	6–7	Always 1
U14, J1006, control inputs, pins 1-6 = bits 0-5, read, default I/O address 325 hex		
CONTROL_IN_7 – CONTROL_IN_12	0–5	0 = input asserted 1 = de-asserted
	6–7	Always 1
U17, J1008, control outputs, pins 1-8 = bits 0-7, write, default I/O address 321 hex		
CONTROL_OUT_1 – CONTROL_OUT_8	0–7	0 = output asserted 1 = de-asserted
U21, J1008, control outputs, pins 9-12 = bits 0-3, write, default I/O address 325 hex		
CONTROL_OUT_9 – CONTROL_OUT_12	0–3	0 = output asserted 1 = de-asserted
U7, J108, internal inputs, pins 9-16 = bits 0-7, read, default I/O address 322 hex		
	0–7	Spare
U8, J108, internal outputs, pins 1-8 = bits 0-7, write, default I/O address 322 hex		
	0–7	Spare
U24, J1017, A status outputs, pins 1-8 = bits 0-7, write, default I/O address 323 hex		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition or in diagnostics mode
	1	Spare
ST_CAL_ACTIVE	2	0 = executing sequence 1 = not executing sequence
ST_DIAG_MODE	3	0 = in diagnostic mode 1 = not in diagnostic mode
ST_TEMP_ALARM	4	0 = any temperature alarm 1 = all temperatures OK
ST_PRESS_ALARM	5	0 = any pressure alarm 1 = all pressures OK
	6–7	Spare
U27, J1018, B status outputs, pins 1-8 = bits 0-7, write, default I/O address 324 hex		
	0–7	Spare

Signal Name	Bit or Channel Number	Description
Relay board digital output (PCF8575), write, default I^2C address 44 hex		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
VENT_VALVE	1	0 = vent valve open 1 = close
PERM_HTR_2 [2, 7]	2	0 = permeation tube #2 heater on 1 = off
	3–4	Spare
GPT_VALVE	5	0 = open GPT bypass valve 1 = close
PHOTO_REF_VALVE	6	0 = photometer valve in reference position 1 = measure position
O3_GEN_VALVE	7	0 = open O_3 generator valve 1 = close
O3_PUMP_ON	8	0 = pump on for photometer to measure O_3 1 = off
O3_DIVERT_VALVE [7]	9	0 = open O_3 divert valve 1 = close
OUTPUT_VALVE_B [1, 7]	10	0 = open output shut-off valve B 1 = close
PERM_VALVE_1 [6, 7]	11	0 = open permeation tube #1 valve 1 = close
PERM_VALVE_2 [2, 7]	12	0 = open permeation tube #2 valve 1 = close
PERM_HTR_1 [6, 7]	13	0 = permeation tube #1 heater on 1 = off
PHOTO_LAMP_HEATER	14	0 = O_3 photometer lamp heater on 1 = off
O3_GEN_HEATER	15	0 = O_3 generator lamp heater on 1 = off

Signal Name	Bit or Channel Number	Description
Valve board digital output (PCA9557), write, default I^2C address 3A hex		
VALVE_WATCHDOG [7]	0	Alternate between 0 and 1 at least every 5 seconds to keep valve board active
CYL_VALVE_1	1	1 = open cylinder gas valve 1 0 = close
CYL_VALVE_2 [7]	2	1 = open cylinder gas valve 2 0 = close
CYL_VALVE_3 [7]	3	1 = open cylinder gas valve 3 0 = close
CYL_VALVE_4 [7]	4	1 = open cylinder gas valve 4 0 = close
PURGE_VALVE [7]	5	1 = open purge valve 0 = close
INPUT_VALVE	6	1 = open input (zero-air) shut-off valve 0 = close
DIL_VALVE_2 [5, 7]	7	1 = open diluent valve #2 0 = open diluent valve #1
Front panel I^2C keyboard, default I^2C address 4E hex		
MAINT_MODE	5 (input)	0 = maintenance mode 1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language 1 = select first language (English)
SEQUENCE_LED [7]	8 (output)	0 = sequence LED on (executing sequence) 1 = off
AUTO_TIMER_LED	9 (output)	0 = automatic timer LED on (automatic sequence timer enabled) 1 = off
FAULT_LED	10 (output)	0 = fault LED on 1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only) 1 = off

Signal Name	Bit or Channel Number	Description
Rear board primary MUX analog inputs		
PHOTO_DET	0	Photometer detector reading
O3_GEN_REF_DET	1	O_3 generator reference detector reading
DIL_PRESS	2	Diluent pressure
CAL_PRESS	3	Cal. gas pressure
	4	Temperature MUX
O3_PERM_PRESS	5	Ozone/perm tube pressure
	6–7	Spare
MFC_FLOW_3 [4]	8	MFC 3 (cal. gas #2) flow output
REF_4096_MV	9	4.096V reference from MAX6241
PHOTO_FLOW	10	Photometer flow
PHOTO_SAMP_PRES	11	Photometer sample pressure
MFC_FLOW_1	12	MFC 1 (diluent) flow output
MFC_FLOW_2	13	MFC 2 (cal. gas #1) flow output
	14	DAC loopback MUX
REF_GND	15	Ground reference
Rear board temperature MUX analog inputs		
BOX_TEMP	0	Internal box temperature
PHOTO_SAMP_TEMP	1	Photometer sample temperature
PHOTO_LAMP_TEMP	2	Photometer lamp temperature
O3_GEN_TEMP	3	O_3 generator lamp temperature
PERM_TEMP_1 [6]	4	Permeation tube #1 temperature
PERM_TEMP_2 [2]	5	Permeation tube #2 temperature
PWR_SPLY_TEMP [8]	6	Power supply temperature.
	7	Spare
Rear board DAC MUX analog inputs		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback
Rear board analog outputs		
MFC_DRIVE_1	0	MFC 1 (diluent) flow drive
MFC_DRIVE_2	1	MFC 2 (cal. gas #1) flow drive
MFC_DRIVE_3 [4]	2	MFC 3 (cal. gas #2) flow drive
TEST_OUTPUT	3	Test measurement output
I^2C analog output (AD5321), default I^2C address 18 hex		
PHOTO_LAMP_DRIVE	0	O_3 photometer lamp drive (0–5V)
I^2C analog output (AD5321), default I^2C address 1A hex		
O3_GEN_DRIVE	0	O_3 generator lamp drive (0–5V)

Signal Name	Bit or Channel Number	Description

[1] Must be enabled with a factory option bit.

[2] Dual permeation tube option.

[4] Triple-MFC option.

[5] Dual diluent option.

[6] Permeation tube option.

[7] Not present on T750 Portable.

[8] T750 portable only

APPENDIX A-5: MODBUS Register Map

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)		
0	Actual cal. gas flow rate	LPM
2	Actual diluent flow rate	LPM
4	Photometer measured ozone concentration	PPB
6	Ozone generator reference detector reading	mV
8	Ozone generator flow rate	LPM
10	Ozone generator lamp drive	mV
12	Ozone generator lamp temperature	°C
14	Cal. gas pressure	PSIG
16	Diluent pressure	PSIG
18	Regulator pressure	PSIG
20	Internal box temperature	°C
22	Permeation tube #1 temperature [3]	°C
24	Permeation tube flow rate [3]	LPM
26	Photometer detector measure reading	mV
28	Photometer detector reference reading	mV
30	Photometer sample flow rate	LPM
32	Photometer lamp temperature	°C
34	Photometer sample pressure	Inches Hg
36	Photometer sample temperature	°C
38	Photometer slope computed during zero/span bench calibration	—
40	Photometer offset computed during zero/span bench calibration	PPB
42	Ground reference	mV
44	Precision 4.096 mV reference	mV
46	Permeation tube #2 temperature [1]	°C
48	Ozone Gen Fraction [2]	—

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Discrete Input Registers (single-bit; read-only)		
0	System reset warning	
1	Box temperature warning	
2	Photometer lamp temperature warning	
3	O_3 generator lamp temperature warning	
4	Permeation tube #1 temperature warning [3]	
5	Photometer reference warning	
6	Photometer lamp stability warning	
7	O_3 generator reference detector warning	
8	Regulator pressure warning	
9	Any MFC pressure outside of warning limits	
10	Any MFC drive less than 10% of full scale or greater than full scale	
11	Any MFC sensor offset greater than allowable limit	
12	Rear board communication warning	
13	Relay board communication warning	
14	Valve board communication warning	
15	O_3 generator or photometer lamp I^2C driver chip communication warning	
16	Front panel communication warning	
17	Firmware is unable to communicate with any MFC	
18	Analog calibration warning	
19	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	O_3 generator not yet stabilized	
21	Permeation tube #2 temperature warning [1]	
MODBUS Coil Registers (single-bit; read/write)		
00-99	Trigger execution of sequence whose name begins with “00” - “99”. Turning a coil on executes a sequence. Turning a coil off does nothing. When reading coils, the value indicates which sequence is executing. If a coil is on, the sequence is executing; if off the sequence is not executing. Supports nested sequences, so multiple sequence coils may be on simultaneously.	
100	Turning coil on turns on purge. Turning coil off does nothing. When reading coil, the value indicates whether purge is active. If on, purge is active; if off, purge is not active. Purge may be invoked within a sequence, so purge coil may be on at the same time as a sequence coil.	
101	Turning coil on puts instrument in standby. Turning coil off does nothing. When reading coil, the value indicates whether instrument is in standby mode. If on, instrument is in standby; if off, instrument is not in standby.	
200-211	Connected to the control outputs (CONTROL_OUT_1– CONTROL_OUT_12). These coils may be turned both on and off. Reading the coils indicates the current state.	

[1] Dual permeation tube option.

[2] Low range option.

[3] Permeation tube option.

APPENDIX A-6: Terminal Command Designators

Table A-5: Terminal Command Designators

COMMAND	ADDITIONAL COMMAND SYNTAX	DESCRIPTION
? [ID]		Display help screen and commands list
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL|name|hexmask	Display test(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL|name|hexmask	Disable test(s)
W [ID]	SET ALL|name|hexmask	Display warning(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL|name|hexmask	Clear warning(s)
C [ID]	ZERO|LOWSPAN|SPAN [1|2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO|SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON|OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

Table A-6: Terminal Key Assignments

TERMINAL KEY ASSIGNMENTS	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
COMPUTER MODE KEY ASSIGNMENTS	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

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APPENDIX B - Spare Parts

Note **Use of replacement parts other than those supplied by Teledyne Advanced Pollution Instrumentation (TAPI) may result in non-compliance with European standard EN 61010-1.**

Note **Due to the dynamic nature of part numbers, please refer to the TAPI Website at http://www.teledyne-api.com or call Technical Support at 800-324-5190 for more recent updates to part numbers.**

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LIST, SPARE PARTS, T750

(08205A, DCN7055)

Item number	Product name
019320100	CBL, GROUND STRAP (4") RT/RT (PA)
079270000	ASSY, OPTICAL BENCH, T750
005100000	RETAINER, TUBE, M400/E M700E/M703E (KB)
041200000	PCA, DET PREAMP w/OP20
04120000V	PCA, DET PREAMP, BENCH, M400E, 703E *
041240001	MANIFOLD, DETECTOR, (KB)
041270000	LAMP BLOCK, (KB)
041280000	LAMP SPACER, (KB)
051800200	ASSY, HARNESS, T750 (KB)
058430001	FT 40 FITTING BODY, SILCOSTEEL COATED
FT0000040	BLKHD, SS, 1/4" TUBE TO 1/4" TUBE (KB)
Y5843000P	FT 40 FITTING BODY, SILCOSTEEL COATED
067300100	PCA, AUX-I/O BOARD, ETHERNET
067390000	CBL, CPU ETHERNET TO AUX I/O PCA(PA)
067410000	CBL, CPU USB TO FRONT PANEL, T-SERIES(PA)
067600200	OPTION, USB COM PORT
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067380000	CBL, CPU COM TO AUX I/O PCA
073210000	PCA, PRES/FLOW Board, 2-P (FREESCALE)
074820000	CABLE, HDMI, T-SERIES(PA)
079490000	ASSY, INPUT MANIFOLD
056440000	ASSY, VALVE (VA23) (B/F)
056450000	ASSY, VALVE (VA67) (B/F)
079480000	INTAKE MANIFOLD, BLOCK, T750
FT0000008	STRAIGHT, SS, 1/8" TUBE TO 1/8" MALE NPT (KB)
FT0000012	STRAIGHT, SS, 1/4" TUBE TO 1/8" MALE NPT (KB)
FT0000015	ELBOW, SS, 1/8" TUBE TO 1/8" MALE NPT (KB)
FT0000066	PORT CONNECTOR, SS, 1/4" TUBE TO 1/8" TUBE (KB)
FT0000213	TEE-TTM, SS, 1/4", 4TTM2-316 (HK)
080070000	ASSY, PWR DISTRIBUTION
058800000	ASSY, THERMISTOR, OVEN
079720000	PCA, DC Power Distribution Board
080080000	SHIELD, PWR SUPPLY
081430000	ASSY, FAN 1" (FA16)
080410000	ASSY, BB CHASSIS, T750 (KB)
079170000	CHASSIS, BASE PLATE, T750
080300000	ASSY, FRONT PANEL, T750
067900000	LCD MODULE, W/TOUCHSCREEN(PA)
079190000	FRONT PANEL, PLATE, T750
079370000	BEZEL, TOUCH SCREEN, T750
HW0000397	HANDLE, 7/16 x 9/32 OVAL, 8-32, 4" x 1"H (VMI)
HW0000756	HINGE, TOP PANELS, RIGHT, T750
HW0000763	HINGE, TOP PANELS, LEFT, T750
080310000	ASSY, REAR PANEL, T750
040010000	ASSY, FAN REAR PANEL (B/F)
FA0000012	FAN, BRUSHLESS, 12VDC, 60MM
058021400	PCA, MTHRBRD, GEN 5-ICOP, CAL (PA)
067240000	CPU, PC-104, VSX-6154E, ICOP *(PA)
068810000	PCA, LVDS TRANSMITTER BOARD

LIST, SPARE PARTS, T750

(08205A, DCN7055)

Item number	Product name
079180000	REAR PANEL, PLATE, T750
CN0000073	POWER ENTRY, 120/60 (KB)
FA0000013	FAN, GUARD, 60MM
HW0000287	HOLE PLUG, 3/4", NYLON, M450H NEMA (VMI)
HW0000458	RIVET, SNAP PLASTIC, FAN,LONG
HW0000063	HOLE PLUG (VMI)
HW0000759	GROMMET EDGING, 1/8", PLASTIC w/ METAL CORE
080430000	ASSY, PORTABLE CASE, T750
079530000	BRACKET, COVERS LANDING
079360000	BRACKET, SIDE RAIL
HW0000685	LATCH, MAGNETIC, FRONT PANEL (KB)
080420000	ASSY, CARRY CASE, T750
080970000	OUTER MASK, PORTABLE, CAL
080640000	OPTION, OZONE, CAL T750 *
073210100	PCA, PRES/FLOW Board, 1-P (FREESCALE)
079220000	ASSY, GPT CHAMBER, T750
018710100	FOAM, SINGLE GPT VOLUME, M700/M702
IN0000001	INSULATION
028240000	REACTION CHAMBER, GPT, M700, M702 (PA)
FT0000051	TEE-TTT, T, 1/4" TUBE TO 1/4" TUBE TO 1/4" TUBE (PA)
FT0000151	CROSS, T, 1/4'' TUBE TO 1/4" TUBE AND 1/8" TUBE TO 1/8" TUBE
079230000	ASSY, GPT VALVE, T750
016590100	ASSY, GPT VALVE
FT0000011	STRAIGHT, B, 1/4" TUBE TO 1/8" MALE NPT (KB)
FT0000016	ELBOW, B, 1/4" TUBE TO 1/8" MALE NPT (KB)
VA0000020	VALVE, 3-WAY, SS (PA)
079240000	ADAPTER PLATE -GPT VALVE
079300000	ASSY, O3 GEN, W/PCB, T750
000940100	CD, ORIFICE, .003 GREEN (KB)
054870000	ASSY, SEALING BOLT, CAL O3GEN
054870100	SEALING BOLT, CAL O3GEN (KB)
OR0000034	ORING, 2-011V FT10 (PA)
054880000	RETAINER, LAMP, O3 GEN, M700E/M703E(KB)
063110000	PCA, DC HEATER/THERM, 100W
079290000	ASSY, O3 GEN DRV, T750
041660000	PCA, UV LAMP P/S, w/HW269 SPACER
041660100	PCA, UV LAMP P/S, O3 GEN, *
079280000	BRACKET, O3 UV LAMP PCB
080090000	SHIELD, O3 PCA
HW0000327	HEATSINK CLIP, TO-220 (VMI)
HW0000356	PAD, THERMAL, TO-220, W/ ADHV (VMI)
079310000	HOUSING, O3 GEN, T750
079320000	BASE, O3 GEN, T750
079500000	INSULATOR, OZONE GENERATOR, T750
080990000	ASSY, O3 GEN LAMP (OP48)
OP0000048	OZONE LAMP, 1 INCH
081440000	ASSY, VALVE (VA24)
VA0000024	VALVE, MANIFOLD, 3-WAY CLIPPARD
FL0000001	FILTER, SS (PA)

LIST, SPARE PARTS, T750

(08205A, DCN7055)

Item number	Product name
FT0000014	ELBOW, B, 1/8'' TUBE TO 1/8'' MALE NPT (KB)
FT0000202	NIPPLE, B, 1/4" TUBE TO 10-32 (KB)
FT0000317	ELBOW, B, 10-32 MALE VITON TO 1/8" TUBE (KB)
FT0000327	ELBOW VITON, SS, 1/8" TUBE TO 10-32
FT0000446	TEE-TFM, B, 1/8" T TO 10-32 F TO 10-32 M
FT0000451	CAP, B, 1/8", MINIATURE BESWICK
OR0000001	ORING, 2-006VT *(KB)
OR0000048	ORING, 2-112S
OR0000077	ORING, 2-018V
VA0000076	REGULATOR, 0-50 PSI
FT0000149	PLUG (HEX SOCKET), 1/8" MALE NPT
HW0000150	CLAMP, HOSE, NYLON, 1/4" K62 "AA" (VMI)
009910100	CBL, GROUND STRAP, 4", RT/QC (PA)
047020100	ASSY, PUMP, PU63, 10" leads
046980000	BRACKET, PUMP MOUNT, OZONE SENSOR(KB)
PU0000063	PUMP, 12V DC BRUSHLESS
073210200	PCA, PRES/FLOW Board, 2-P 1-F (FREESCALE)
079200000	ASSY, PHOTOMETER INPUT LOOP
055220000	ASSY, VALVE W/CONN, VA 59
FT0000189	FERRULE, TEFZEL, 1/8" (KB)
FT0000190	NUT, DERLIN, 1/8" (KB)
VA0000059	VALVE, 3-WAY, 12VDC *
079210000	BRACKET, PHOTOMETER INPUT LOOP
079220000	ASSY, GPT CHAMBER, T750
080110000	MASK, PHOTOMETER INPUT LOOP
FT0000036	TEE-TTT, SS, 1/4" TUBE TO 1/4" TUBE TO 1/4" TUBE (KB)
FT0000056	TEE-TTT, SS, 1/8" TUBE TO 1/8" TUBE TO 1/8" TUBE (KB)
FT0000085	PORT CONNECTOR, SS, 1/4" TUBE TO 1/4" TUBE (KB)
FT0000134	BLKHD, SS, 1/4'' TUBE TO 1/8'' TUBE (KB)
FT0000321	PORT CONNECTOR, SS, 1/8" TUBE TO 1/8" TUBE
041300000	EHXAUST MANIFOLD, (PA)
041440000	PCA, DC HTR/TEMP, BENCH
041660500	AKIT, PCA, UV LAMP P/S O3/CAL *
042010000	ASSY, SAMPLE THERMISTOR
003290000	THERMISTOR, BASIC (VENDOR ASSY)(PA)
047760000	ASSY, UV LAMP, BENCH, 400/700/703 *
047750000	LAMP, SOURCE, M400E/M703E, LOW MERCURY
049290000	CLIP, THERMISTOR HOLDER
055370000	DETECTOR COLLAR, PET VERSION(KB)
079520000	ABSORPTION TUBE, QUARTZ, T750
FT0000013	STRAIGHT, T, 1/8" TUBE TO 1/8" MALE NPT (KB)
FT0000191	TEE-TTM, B, 1/4" BARB TO 1/4" BARB TO 10-32 (KB)
FT0000279	HEX EXTENSION, B, 10-32 MALE TO 10-32 FEMALE (KB)
OP0000014	QUARTZ DISC .75 DIAX1/16",(PA)
OP0000031	WINDOW, QUARTZ, 1/2"DIA, .063" THICK (PA)
OR0000026	ORING, 2-110 S604-70
OR0000039	ORING, 2-012V (PA)
OR0000089	ORING, 2-016V
079300100	ASSY, O3 GEN, W/PCB, PHOTO, T750

LIST, SPARE PARTS, T750

(08205A, DCN7055)

Item number	Product name
FT0000332	ORIFICE, B, .009, 10-32 MALE TO 10-32 FEMALE (KB)
079510000	BRACKET, PHOTO MOUNT, T750
FT0000037	STRAIGHT, SS, 1/8" TUBE TO 1/8" TUBE (KB)
FT0000121	STRAIGHT, SS, 1/4" TUBE TO 1/8" TUBE (KB)
FT0000157	ELBOW, SS, 1/8" TUBE TO 1/8" TUBE (KB)
FT0000224	CAP, SS, 1/4" (KB)
079340000	MFC SUBPLATE, T750
081020000	DOM, w/SOFTWARE, T750
FT0000068	TUBE INSERT, SS, 1/4" (KB)
HW0000758	HOLE PLUG, 1-5/16" (FS)
HW0000760	BUSHING SPIL .250 PVC BLACK
HW0000761	BUSHING SPIL .218 PVC BLACK
HW0000766	PLUG, SQUARE, 1/2" CUT OUT

Appendix C Warranty/Repair Questionnaire T750U/T750 (08220B, DCN7055)	TELEDYNE ADVANCED POLLUTION INSTRUMENTATION A Teledyne Technologies Company

CUSTOMER: _____ PHONE: _____

CONTACT NAME: _____ FAX NO. _____

SITE ADDRESS: _____

MODEL TYPE: _____ SERIAL NO.: _____ FIRMWARE REVISION: _____

Are there any failure messages? _____

PLEASE COMPLETE THE FOLLOWING TABLE (Depending on options installed, not all test parameters shown will be available in your calibrator):

PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE
A-CAL	LPM*	TARG CAL ± 1%
T-CAL	LPM*	0.001 – 0.100 SLPM
A-DIL	LPM*	TARG DIL ± 1%
T-DIL	LPM*	0.01 – 10 SLPM
O3GEN FRAC		REFERENCE ONLY
O3FLOW [1]	LPM*	T750U 0.160 ± 0.020 SLPM T750 0.100 ± 0.020 SLPM
O3GENDRV [1]	mV	0 – 5000mV
O3LAMPTMP [1]	ºC	48 ± 1ºC
CAL PRES	PSI	25 – 35PSI
DIL PRES	PSI	25 – 35PSI
REG PRES [1]	PSI	T750U 10 ± 1PSI / T750 20 ± 1PSI
A-GAS		T-GAS ± 1%
T-GAS		
A-O3 [1]		T-O3 ± 1%
T-O3 [1]		
T-FLW	LPM*	
BOX TMP	ºC	AMBIENT ± 5ºC
PWRSPLY TEMP	ºC	BOX TMP ± 10 ºC
PH MEAS [2]	mV	2500 – 4800mV
PH REF [2]	mV	2500 – 4800mV
PH FLW [2]	LPM	0.720 – 0.880LPM
PH LTEMP [2]	ºC	58 ± 1ºC
PH PRES [2]	IN-HG	AMBIENT ± 1 IN-HG
PH STEMP [2]	ºC	AMBIENT ± 3ºC
PH SLOPE [2]		0.85-1.15
PH OFFST [2]	PPB	0 ±10 PPB

[1] If ozone generator option installed. [2] If photometer option installed. *Standard flow

TELEDYNE API TECHNICAL SUPPORT
Email: sda_techsupport@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

Appendix C Warranty/Repair Questionnaire T750U/T750 (08220B, DCN7055)	TELEDYNE ADVANCED POLLUTION INSTRUMENTATION A Teledyne Technologies Company

What is measured photometer flow rate _____cc/min

What is measured O_3 generator flow rate? _____cc/min

What is the pressure change during the **AUTO LEAK CHECK** procedure? _____ psi

What are the failure symptoms? _____

_____

_____

_____

What tests have you done trying to solve the problem? _____

_____

_____

_____

_____

Thank you for providing this information. Your assistance enables Teledyne Instruments to respond faster to the problem that you are encountering.

OTHER NOTES: _____

_____

_____

_____

_____

_____

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TELEDYNE API TECHNICAL SUPPORT
Email: sda_techsupport@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

APPENDIX D – Interconnect Drawing

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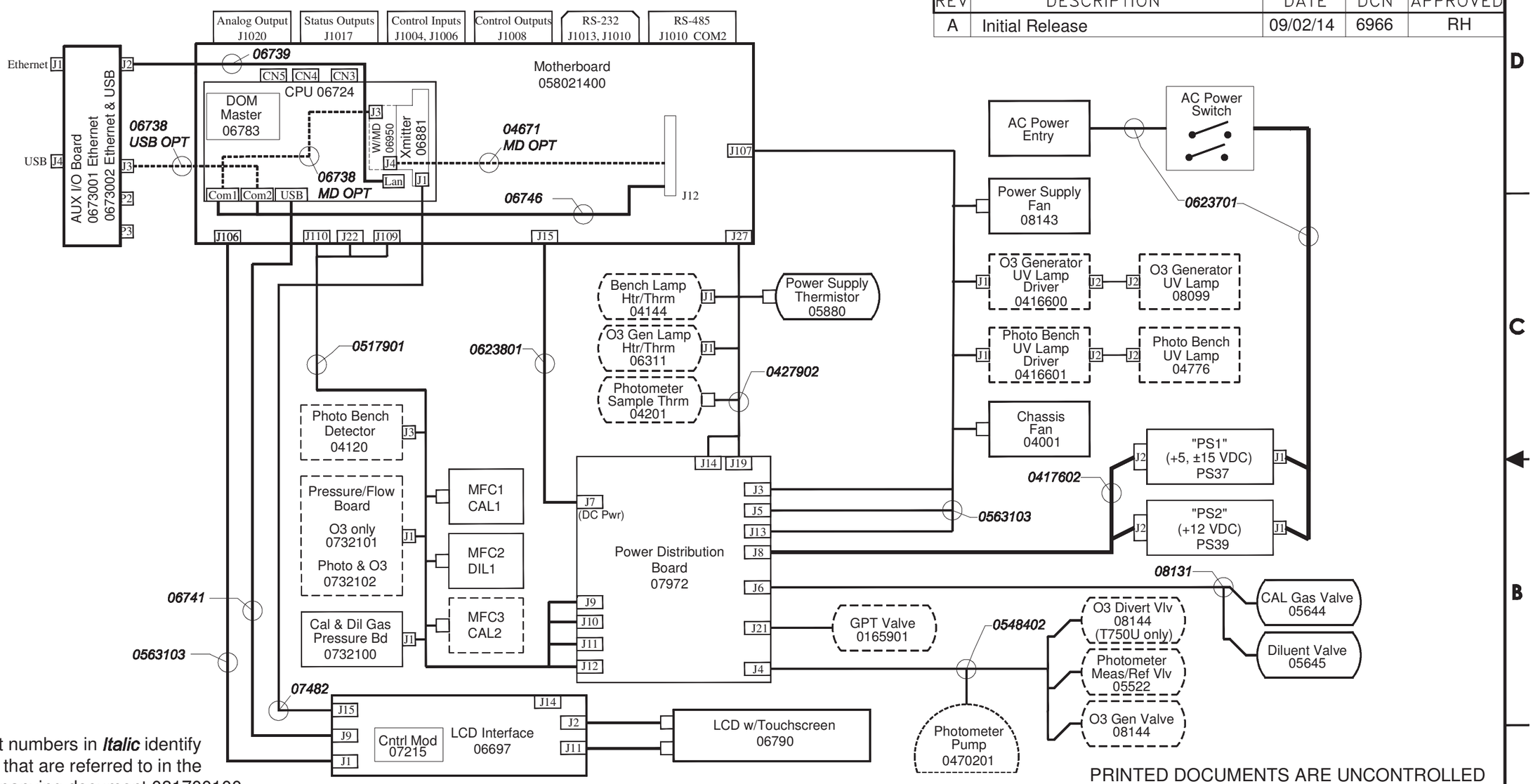
REVISIONS				
REV	DESCRIPTION	DATE	DCN	APPROVED
A	Initial Release	09/02/14	6966	RH



Notes:

1. All part numbers in ***Italic*** identify cables that are referred to in the accompanying document 081700100.
2. Multidrop and USB I/O are options in the T750 and T750U.
3. Unless otherwise indicated, all other items in ***dashed*** boxes are options in the T750 but are standard in the T750U.

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THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ± 1/32 DECIMALS ±.03[0.76] ±.010[0.25] ANGULAR ±0° 30'
DO NOT SCALE DRAWING
TREATMENT NA
FINISH
SIMILAR TO

CONTRACT: NA

APPROVALS	DATE
DRAWN KV	5/10
CHECK	
CCB	
ISSUED	

TELEDYNE
Advanced Pollution Instrumentation
A Teledyne Technologies Company

TITLE INTERCONNECT DRAWING T750/U

SIZE	CAGE CODE NO.	DWG. NO.	REV
B	1JZF4	08170	A

SCALE 1/1 FILE 08170 SHEET 1 OF 1