TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

Operation Manual

Model T700
Dynamic Dilution Calibrator

© TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)
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ABOUT TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)

Teledyne Advanced Pollution Instrumentation, Inc. (TAPI) is a world leader in the design and manufacture of precision analytical instrumentation for trace gas analysis. Founded in San Diego, California, in 1988, TAPI introduced a complete line of Air Quality Monitoring (AQM) instrumentation, which complied with the Environmental Protection Administration (EPA) requirements for the measurement of criteria gases consisting of CO, SO2, NOX and Ozone.

Since that time, TAPI has introduced many features to these products and has grown to the position of the leading producer of AQM instrumentation, providing state of the art analytical products on a world wide basis. Our instruments comply with US EPA regulations as well as a number of other international requirements.

NOTICE OF COPYRIGHT

TRADEMARKS

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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, and are 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

Technical Assistance regarding the use and maintenance of this instrument or any other Teledyne API product can be obtained by contacting Teledyne API's Customer Service Department:

Telephone: 800-324-5190

Email: api-customerservice@teledyne.com
or by accessing various service options on our website at http://www.teledyne-api.com/

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WARRANTY

WARRANTY POLICY (02024D)

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

COVERAGE

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

NON-API MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by Teledyne API is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturers warranty.

GENERAL

During the warranty period, Teledyne API warrants each Product manufactured by Teledyne API to be free from defects in material and workmanship under normal use and service. Expendable parts are excluded.

If a Product fails to conform to its specifications within the warranty period, API shall correct such defect by, in API's discretion, repairing or replacing such defective Product or refunding the purchase price of such Product.

The warranties set forth in this section shall be of no force or effect with respect to any Product: (i) that has been altered or subjected to misuse, negligence or accident, or (ii) that has been used in any manner other than in accordance with the instruction provided by Teledyne API, or (iii) not properly maintained.

THE WARRANTIES SET FORTH IN THIS SECTION AND THE REMEDIES THEREFORE ARE EXCLUSIVE AND IN LIEU OF ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR PARTICULAR PURPOSE OR OTHER WARRANTY OF QUALITY, WHETHER EXPRESSED OR IMPLIED. THE REMEDIES SET FORTH IN THIS SECTION ARE THE EXCLUSIVE REMEDIES FOR BREACH OF ANY WARRANTY CONTAINED HEREIN. API SHALL NOT BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF OR RELATED TO THIS AGREEMENT OF TELEDYNE API'S PERFORMANCE HEREUNDER, WHETHER FOR BREACH OF WARRANTY OR OTHERWISE

TERMS AND CONDITIONS

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

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 "Packing Components for Return to Teledyne API's Customer Service" in the *Primer on Electro-Static Discharge* section of this manual, and for RMA procedures please refer to our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

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ABOUT THIS MANUAL

Presented here is information regarding the documents that are included with this manual (Structure) and how the content is organized (Organization).

STRUCTURE

This T700 manual, PN 06873, is comprised of multiple documents, assembled in PDF format, as listed below.

Part No.	Rev	Name/Description
06873	x1	Operation Manual, T700 Dynamic Dilution Calibrator
		Manual Addendum, Relay PCA
06874		Appendix A, Menu Trees and related software documentation, Rev.
06852		Spare Parts List (in Appendix B of this manual)
06875		Appendix C, Repair Form
		Interconnect Diagram, T700 (in Appendix D of this manual)
		Interconnect List, T700 (in Appendix D of this manual)
		SCH, PCA xxxxx, UV DETECTOR, M400E
		SCH, PCA xxxxx, DC HEATER/TEMP SENSOR
		SCH, PCA xxxxx, UV LAMP POWER SUPPLY, M400E
		SCH, PCA xxxxx, Touchscreen, T-SERIES
		SCH, PCA xxxxx, Pressure/Flow Transducer Interface
		SCH, PCA xxxxx, INTRFC,ETHERNET,T-SERIES
		SCH, PCA xxxxx, RELAY CARD, M100E/M200E/M400E
		SCH, PCA xxxxx, VALVE DRIVER, T700
		SCH, PCA xxxxx ADPTR, EXT VALVE DRIVER, T700
		SCH, PCA xxxxx, MTHERBRD, T-SER, GEN-xx

Note **We recommend that this manual be read in its entirety before any attempt is made to operate the instrument.**

ORGANIZATION

This manual is divided among three main parts and a collection of appendices at the end.

Part I contains introductory information that includes an overview of the calibrator, descriptions of the available options, specifications, installation and connection instructions, and the initial calibration and functional checks.

Part II comprises the operating instructions, which include basic, advanced and remote operation, calibration, diagnostics, testing, validating and verifying.

Part III provides detailed technical information, such as theory of operation, maintenance, and troubleshooting and repair along with Frequently Asked Questions (FAQs) and a glossary. It also has a section that provides important information about electro-static discharge and avoiding its consequences.

The appendices at the end of this manual provide support information such as, version-specific software documentation, lists of spare parts and schematics.

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REVISION HISTORY

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

2010, T700 Manual, PN06873 Rev x1, DCNxxxx				
Document	**PN**	**Rev**	**DCN**	**Change Summary**
				Initial Release
Documents included in initial release:				

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TABLE OF CONTENTS

PART I – GENERAL INFORMATION 21
1. INTRODUCTION 23
1.1. T700 Calibrator Overview 23
2. SPECIFICATIONS AND APPROVALS 25
2.1. Specifications 25
2.2. CE Mark Compliance 26
3. GETTING STARTED 27
3.1. Unpacking and Initial Setup 27
3.1.1. Calibrator Layout 28
3.1.1.1. Front Panel 28
3.1.1.2. Rear Panel 31
3.1.1.3. Internal Layout 33
3.1.2. Electrical Connections 36
3.1.2.1. Power Connection 36
3.1.2.2. Analog Output Connections 36
3.1.2.3. Connecting the Status Outputs 37
3.1.2.4. Connecting the Control Inputs 38
3.1.2.5. Connecting the Control Outputs 40
3.1.2.6. Connecting the Serial Ports 41
3.1.2.7. Connecting to a LAN or the Internet 41
3.1.2.8. Connecting to a Multi-drop Network 41
3.2. Pnenumatic Connections 41
3.2.1. About Diluent Gas (Zero Air) 41
3.2.2. About Calibration Gas 42
3.2.2.1. NIST Traceable Calibration Gas Standards 42
3.2.2.2. Minimum Calibration Gas Source Concentration 45
3.2.3. Connecting Diluent Gas to the Calibrator 45
3.2.4. Connecting Calibration Source Gas to the T700 Calibrator 45
3.2.5. Connecting Gas Outputs from the Calibrator 46
3.2.5.1. Set up for Direct Connections to Other Instruments 46
3.2.5.2. Connecting the Calibrator to a Sample Gas Manifold 47
3.2.5.3. Connecting the Calibrator to a Calibration Manifold 48
3.2.5.4. Connecting the Calibrator to a Dual Span Gas / Zero Air Calibration Manifold 49
3.2.6. Other Pneumatic Connections 50
3.2.6.1. O_3 Generator Option 50
3.2.6.2. O_3 Generator with Photometer Option 50
3.3. Initial Operation 51
3.3.1. Start Up 51
3.3.2. Warm Up 52
3.3.3. Warning Messages 52
3.3.4. Functional Check 54
3.3.5. Setting Up the Calibration Gas Inlet Ports 55
3.3.6. Default Gas Types 55
3.3.7. User Defined Gas Types 55
3.3.7.1. User Defined Gas Types – General 55
3.3.7.2. User Defined Gas Types – Defining the Gas Name 56
3.3.7.3. User Defined Gas Types – Setting the MOLAR MASS 57
3.3.7.4. Enabling and Disabling Gas Types 59
3.3.8. Defining Calibration Source Gas Cylinders 60
3.3.8.1. Setting Up the Ports with Single Gas Cylinders 60
3.3.8.2. Setting Up the Ports with Multiple Gas Cylinders 62
3.3.9. Selecting an Operating Mode the O_3 Generator 63
3.3.9.1. CNST (CONSTANT) 63
3.3.9.2. REF (REFERENCE) 63

3.3.9.3. BNCH (BENCH) 63
3.3.10. Setting the T700's Total Gas Flow Rate 64
4. FREQUENTLY ASKED QUESTIONS AND GLOSSARY 67
4.1. FAQ's 67
4.2. Glossary 67
5. OPTIONAL HARDWARE AND SOFTWARE 71
5.1. Ozone Options 71
5.1.1. Internal Ozone Generator (OPT 01A) 71
5.1.2. UV Photometer Module (OPT 02A) 73
5.2. Gas Flow Options 75
5.2.1. Flow Rate Options (OPT 07A, OPT 7B, OPT 08A & OPT 08B) 75
5.2.2. Multiple Calibration Source Gas MFC 75
5.3. Rack Mount Kits (OPT 20A, OPT 20B & OPT 21) 77
5.4. Carrying Strap Handle (OPT 29) 77
5.5. Spare Parts kits 78
5.5.1. T700 Expendables Kit (OPT 46A) 78
5.5.2. T700 Spare Parts Kit (OPT 46B & OPT 46C) 78
5.6. Communication Options 78
5.6.1. Serial Communications Cables (OPT 60A, 60B, 60C, and 60D) 78
5.6.2. RS-232 Multi-drop (OPT 62) 79
5.7. Additional Manual (OPT 70A & OPT 70B) 79
5.8. External Valve Driver (OPT 48A & OPT 48B) 79
5.9. NIST Traceable, Primary Standard Certification (OPT 95A, OPT 95B & OPT 95C) 80
5.10. Permeation Tube Oven Option (OPT 05) 81
5.10.1. Permeation Tube Setup for the T700 83
5.10.2. Permeation Tube Calculation 84
5.11. Extended Warranty (OPT 92B & OPT 92C) 85
5.12. Dual Gas Output (NO_y – Special) (OPT 73) 85
PART II – OPERATING INSTRUCTIONS 88
6. BASIC OPERATION 91
6.1. Test Functions 92
6.2. Overview of Operating modes 94
6.3. STANDBY MODE 96
6.4. GENERATE MODE 98
6.4.1. General Information about the GENERATE mode 98
6.4.2. GENERATE → AUTO: Basic Generation of Calibration Mixtures 100
6.4.3. GENERATE → MAN: Generating Calibration Mixtures Manually 102
6.4.3.1. Determining the Source Gas Flow Rate 102
6.4.3.2. Determining the Diluent Gas Flow Rate 103
6.4.3.3. Determining the Diluent Gas Flow Rate with the Optional O_3 Generator Installed 103
6.4.3.4. Setting the Source Gas and Diluent Flow Rates Using the GENERATE → MAN Menu 104
6.4.4. GENERATE → GPT: Performing a Gas Phase Titration Calibration 105
6.4.4.1. GPT Theory 105
6.4.4.2. Choosing an Input Concentration for the NO. 105
6.4.4.3. Determining the TOTAL FLOW for GPT Calibration Mixtures 106
6.4.4.4. T700 Calibrator GPT Operation 107
6.4.4.5. Initiating a GPT Calibration Gas Generation 108
6.4.5. GENERATE → GPTPS: Performing a Gas Phase Titration Pre-Set 109
6.4.5.1. T700 Calibrator GPTPS Operation 109
6.4.5.2. Initiating a GPT Pre-Set 111
6.4.6. GENERATE → PURGE: Activating the T700's Purge Feature 112
6.4.7. GENERATE →ACT>: VIEWING CONCENTRATIONS Generated from Multi-Gas Cylinders 114
6.4.7.1. Using the T700 Calibrator as a O_3 Photometer 114
6.5. AUTOMATIC CALIBRATION SEQUENCES 115
6.5.1. SETUP → SEQ: Programming Calibration Sequences 115

6.5.1.1. Activating a Sequence from the T700 Front Panel ... 117
6.5.1.2. Naming a Sequence ... 118
6.5.1.3. Setting the Repeat Count for a Sequence ... 119
6.5.1.4. Using the T700's Internal Clock to Trigger Sequences ... 120
6.5.1.5. Setting Up Control Inputs for a Sequence ... 123
6.5.1.6. Setting Up Control Outputs for a Sequence ... 124
6.5.1.7. Setting the PROGRESS Reporting Mode for the Sequences ... 125
6.5.2. Adding Sequence Steps ... 126
6.5.2.1. The GENERATE Step ... 127
6.5.2.2. The GPT Step ... 128
6.5.2.3. The GPTPS Step ... 129
6.5.2.4. The PURGE Step ... 130
6.5.2.5. The STANDBY Step ... 130
6.5.2.6. The DURATION Step ... 131
6.5.2.7. The EXECSEQ Step ... 132
6.5.2.8. The CC OUTPUT Step ... 133
6.5.2.9. The MANUAL Gas Generation Step ... 134
6.5.2.10. Deleting or Editing an Individual Step in a Sequence ... 135
6.5.3. Deleting a Sequence ... 136
6.6. SETUP → CFG ... 137
6.7. SETUP → CLK ... 138
6.7.1. Setting the Internal Clock's Time and Day ... 138
6.7.2. Adjusting the Internal Clock's Speed ... 139
6.8. SETUP → PASS ... 140
6.9. SETUP → DIAG → TEST CHAN OUTPUT: Using the TEST Channel Analog Output ... 142
6.9.1. Configuring the TEST CHANNEL Analog Output ... 142
6.9.1.1. The Analog I/O Configuration Submenu. ... 142
6.9.1.2. Selecting a Test Channel Function to Output ... 144
6.9.1.3. TEST CHANNEL VOLTAGE RANGE Configuration ... 146
6.9.1.4. Turning the TEST CHANNEL Over-Range Feature ON/OFF ... 147
6.9.1.5. Adding a Recorder Offset to the TEST CHANNEL ... 148
6.9.2. TEST CHANNEL CALIBRATION ... 149
6.9.2.1. Enabling or disabling the TEST CHANNEL Auto-Cal Feature ... 149
6.9.2.2. Automatic TEST CHANNEL Calibration ... 150
6.9.2.3. Manual Calibration of the TEST CHANNEL Configured for Voltage Ranges ... 152
6.9.3. AIN Calibration ... 154
6.10. SETUP → MORE → VARS: Internal Variables (VARS) ... 155
6.11. SETUP → LVL: Setting up and using LEADS (Dasibi) Operating Levels ... 157
6.11.1. General Information about LEADS LEVELS ... 157
6.11.2. Dot commands ... 157
6.11.3. Levels ... 158
6.11.4. Activating an existing LEVEL ... 158
6.11.5. Programming New LEVELS ... 159
6.11.5.1. Creating a GENERATE LEVEL ... 160
6.11.5.2. Creating a GPT LEVEL ... 161
6.11.5.3. Creating a GPTPS LEVEL ... 162
6.11.5.4. Creating a MANUAL LEVEL ... 163
6.11.5.5. Editing or Deleting a LEVEL ... 164
6.11.6. CONFIGURING LEVEL Status Blocks ... 165
7. REMOTE OPERATION ... 167
7.1. Using the AnalyZer's Communication Ports ... 167
7.1.1. RS-232 DTE and DCE Communication ... 167
7.1.2. COMM Port Default Settings and Connector Pin Assignments ... 168
7.1.3. COMM Port Baud Rate ... 171
7.1.4. COMM Port Communication Modes ... 172
7.1.5. COMM Port Testing ... 174

7.1.6. Machine ID 175
7.1.7. Terminal Operating Modes 176
7.1.7.1. Help Commands in Terminal Mode 176
7.1.7.2. Command Syntax 177
7.1.7.3. Data Types 177
7.1.7.4. Status Reporting 178
7.1.7.5. COMM Port Password Security 179
7.2. Remote Access by Modem 180
7.2.1. Multi-drop RS-232 Set Up 182
7.3. RS-485 Configuration of COM2 184
7.4. Remote Access via the Ethernet 186
7.4.1. Configuring the Ethernet Interface using DHCP 186
7.4.1.1. Manually Configuring the Network IP Addresses 189
7.4.2. Changing the Calibrator's HOSTNAME 191
7.5. APICOM Remote Control Program 192
8. CALIBRATION AND VERIFICATION 194
8.1. Viewing the Performance Statistics for the T700's MFC's 194
8.2. Calibrating the Output of the T700's MFC's 195
8.2.1. Setup for Verification and Calibration of the T700's MFC's 196
8.2.2. Verifying and Calibrating the T700's MFC's 197
8.3. Verifying and Calibrating the T700's Optional O_3 Photometer 198
8.3.1. Setup for Verifying O_3 Photometer Performance 198
8.3.2. Verifying O_3 Photometer Performance 199
8.3.3. Setup for Calibration of the O_3 Photometer 200
8.3.3.1. Setup Using Direct Connections 200
8.3.3.2. Setup Using a Calibration Manifold 201
8.3.3.3. Calibration Manifold Exhaust/Vent Line 201
8.3.4. Performing an External Calibration of the O_3 Photometer 202
8.3.4.1. Photometer Zero Calibration 202
8.3.4.2. Photometer Span Calibration 203
8.3.5. O_3 Photometer Dark Calibration 204
8.3.6. O_3 Photometer Gas Flow Calibration 205
8.4. Calibrating the O_3 Generator 206
8.4.1. Setup for Verification and Calibration the O_3 Generator 206
8.4.1.1. Setup Using Direct Connections 206
8.4.2. Verifying O_3 Generator Performance 207
8.4.3. O_3 Generator Calibration Procedure 208
8.4.3.1. Viewing O_3 Generator Calibration Points 208
8.4.3.2. Adding or Editing O_3 Generator Calibration Points 209
8.4.3.3. Deleting O_3 Generator Calibration Points 210
8.4.3.4. Turning O_3 Generator Calibration Points ON / OFF 211
8.4.3.5. Performing an Automatic Calibration of the Optional O_3 Generator 212
8.5. T700 Gas Pressure Sensor Calibration 213
8.5.1.1. Calibrating the Diluent, Cal Gas Optional O_3 Generator Pressure Sensors 215
8.5.1.2. Calibrating the Optional O_3 Photometer Sample Gas Pressure Sensors 216
PART III – TECHNICAL INFORMATION 217
9. THEORY OF OPERATION 219
9.1. Basic Principles of Dynamic Dilution Calibration 219
9.1.1. Gas Phase Titration Mixtures for O_3 and NO_2 220
9.2. Pneumatic Operation 221
9.2.1. Gas Flow Control 221
9.2.1.1. Diluent and Source Gas Flow Control 221
9.2.1.2. Flow Control Assemblies for Optional O_3 Components 222
9.2.1.3. Critical Flow Orifices 223
9.2.2. Internal Gas Pressure Sensors 223
9.3. Electronic Operation 225

9.3.1. Overview 225
9.3.2. CPU 226
9.3.2.1. Disk-on-Module (DOM) 227
9.3.2.2. Flash Chip 227
9.3.3. Relay PCA 228
9.3.3.1. Valve Control 229
9.3.3.2. Heater Control 229
9.3.3.3. Relay PCA Status LEDs & Watch Dog Circuitry 229
9.3.3.4. Relay PCA Watchdog Indicator (D1) 230
9.3.4. Valve Driver PCA 231
9.3.4.1. Valve Driver PCA Watchdog Indicator 231
9.3.5. Motherboard 232
9.3.5.1. A to D Conversion 232
9.3.5.2. Sensor Inputs 232
9.3.5.3. Thermistor Interface 232
9.3.5.4. Analog Outputs 232
9.3.5.5. External Digital I/O 233
9.3.5.6. I^2C Data Bus 233
9.3.5.7. Power-up Circuit 233
9.3.6. Input Gas Pressure Sensor PCA 233
9.3.7. Power Supply and Circuit Breaker 234
9.4. Front Panel Touchscreen/Display Interface 235
9.4.1.1. Front Panel Interface PCA 235
9.5. Software Operation 236
9.6. O_3 Generator Operation 237
9.6.1. Principle of Photolitic O_3 Generation 237
9.6.2. O_3 Generator – Pneumatic Operation 238
9.6.3. O_3 Generator – Electronic Operation 239
9.6.3.1. O_3 Generator Temperature Control 240
9.6.3.2. Pneumatic Sensor for the O_3 Generator 241
9.7. Photometer Operation 241
9.7.1. Measurement Method 242
9.7.1.1. Calculating O_3 Concentration 242
9.7.1.2. The Measurement / Reference Cycle 243
9.7.1.3. The Absorption Path 245
9.7.1.4. Interferent Rejection 245
9.7.2. Photometer Layout 246
9.7.3. Photometer Pneumatic Operation 246
9.7.4. Photometer Electronic Operation 247
9.7.4.1. O_3 Photometer Temperature Control 247
9.7.4.2. Pneumatic Sensors for the O_3 Photometer 248
10. MAINTENANCE SCHEDULE & PROCEDURES 249
10.1. Maintenance Schedule 249
10.2. Maintenance Procedures 251
10.2.1. Auto Leak Check 251
10.2.1.1. Equipment Required 251
10.2.1.2. Setup Auto Leak Check 251
10.2.1.3. Performing the Auto Leak Check Procedure 254
10.2.1.4. Returning the T700 to Service after Performing an Auto Leak Check 254
10.2.2. Cleaning or Replacing the Absorption Tube 255
10.2.3. UV Source Lamp Adjustment 256
10.2.4. UV Source Lamp Replacement 257
10.2.5. Adjustment or Replacement of Ozone Generator UV Lamp 258
11. GENERAL TROUBLESHOOTING & REPAIR 261
11.1. General Troubleshooting 261
11.1.1. Fault Diagnosis with WARNING Messages 262

11.1.2. Fault Diagnosis With Test Functions 266
11.1.3. Using the Diagnostic Signal I/O Function 269
11.2. Using the Analog Output Test Channel 270
11.3. Using the Internal Electronic Status LEDs........ 271
11.3.1. CPU Status Indicator 271
11.3.2. Relay PCA Status LEDs 271
11.3.2.1. I^2C Bus Watchdog Status LEDs 271
11.3.2.2. O_3 Option Status LEDs........ 272
11.3.3. Valve Driver PCA STATUS LEDs........ 273
11.4. Subsystem Checkout........ 274
11.4.1. Verify Subsystem Calibration........ 274
11.4.2. AC Main Power 274
11.4.3. DC Power Supply........ 275
11.4.4. I^2C Bus........ 276
11.4.5. Touchscreen Interface 276
11.4.6. LCD Display Module 276
11.4.7. Relay PCA 277
11.4.8. Valve Driver PCA........ 277
11.4.9. Input Gas Pressure / Flow Sensor Assembly 278
11.4.10. PHOTOMETER O_3 Generator Pressure/FLOW SENSOR Assembly 279
11.4.11. Motherboard........ 280
11.4.11.1. A/D Functions 280
11.4.11.2. Test Channel / Analog Outputs Voltage 280
11.4.11.3. Status Outputs........ 281
11.4.11.4. Control Inputs 282
11.4.11.5. Control Outputs 282
11.4.12. CPU 283
11.4.13. The Calibrator Doesn't Appear on the Lan or Internet........ 283
11.4.14. RS-232 Communications........ 284
11.4.14.1. General RS-232 Troubleshooting........ 284
11.4.14.2. Troubleshooting Calibrator/Modem or Terminal Operation........ 284
11.4.15. Temperature Problems 285
11.4.15.1. Box / Chassis Temperature........ 285
11.4.15.2. Photometer Sample Chamber Temperature 285
11.4.15.3. UV Lamp Temperature........ 285
11.4.15.4. Ozone Generator Temperature 286
11.5. Trouble Shooting the Optional O_3 Photometer........ 286
11.5.1. Dynamic Problems with the Optional O_3 Photometer........ 286
11.5.1.1. Noisy or Unstable O_3 Readings at Zero 286
11.5.1.2. Noisy, Unstable, or Non-Linear Span O_3 Readings 287
11.5.1.3. Slow Response to Changes in Concentration........ 287
11.5.1.4. The Analog Output Signal Level Does Not Agree With Front Panel Readings........ 287
11.5.1.5. Cannot Zero........ 287
11.5.1.6. Cannot Span........ 287
11.5.2. Checking Measure / Reference Valve 288
11.5.3. Checking The UV Lamp Power Supply 289
11.6. Trouble Shooting the Optional O_3 generator 290
11.6.1. Checking The UV Source Lamp Power Supply........ 290
11.7. Repair Procedures........ 291
11.7.1. Disk-On-Module Replacement Procedure........ 291
11.8. Technical Assistance........ 291
12. A PRIMER ON ELECTRO-STATIC DISCHARGE........ 293
12.1. How Static Charges are Created........ 293
12.2. How Electro-Static Charges Cause Damage 294
12.3. Common Myths About ESD Damage........ 295
12.4. Basic Principles of Static Control........ 295

12.4.1. General Rules 295
12.4.2. Basic anti-ESD Procedures for Analyzer Repair and Maintenance 297
12.4.2.1. Working at the Instrument Rack 297
12.4.2.2. Working at an Anti-ESD Work Bench 297
12.4.2.3. Transferring Components from Rack to Bench and Back 298
12.4.2.4. Opening Shipments from Teledyne API's Customer Service 298
12.4.2.5. Packing Components for Return to Teledyne API's Customer Service 299

LIST OF FIGURES

Figure 3-1: T700 Front Panel Layout 28
Figure 3-2: Display Screen and Touch Control 29
Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts 30
Figure 3-4: T700 Rear Panel Layout 31
Figure 3-5: T700 Internal Layout – Top View – Base Unit 33
Figure 3-6: T700 Internal Layout – Top View – with Optional O_3 Generator and Photometer 34
Figure 3-7: T700 Pneumatic Diagram – Base Unit 35
Figure 3-8: T700 Pneumatic Diagram – with O_3 Generator and Photometer 35
Figure 3-9: T700 Analog Output Connector 36
Figure 3-10: Status Output Connector 37
Figure 3-11: T700 Digital Control Input Connectors 39
Figure 3-12: T700 Digital Control Output Connector 40
Figure 3-13: Set up for T700 – Connecting the Basic T700 to a Sample Manifold 46
Figure 3-14: Set up for T700 – Connecting the T700 to a Sample Manifold 47
Figure 3-15: Set up for T700 – Connecting the T700 to a Calibration Manifold 48
Another type of calibration setup utilizes separate span gas and the zero air manifolds (see Figure 3-16) 49
Figure 3-16: Set up for T700 – Connecting the T700 to a Dual Span Gas / Zero Air Manifold 49
Figure 5-1: Internal Pneumatics for T700 Calibrator with Optional O_3 Generator and GPT Chamber. 72
Figure 5-2: Internal Pneumatics for T700 Calibrator with Optional O_3 Generator and Photometer 74
Figure 5-3: Basic T700 with Multiple Calibration Gas MFC's 76
Figure 5-4: T700 with Multiple Calibration Gas MFC's and O_3 Options OPT 01A and OPT 02A Installed 77
Figure 5-5: T700 Rear Panel Valve Driver Installed 79
Figure 5-6: Valve Driver PCA Layout 80
Figure 5-7: Permeation Tube Gas Generator Option 81
Figure 5-8: Pneumatic Diagram of T700 with Permeation Generator 82
Figure 5-9: Internal Pneumatics for T700 Calibrator with Optional Dual Gas Output (NO_y – Special) 87
Figure 6-1: Viewing T700 Test Functions 92
Figure 6-2: Front Panel Display 94
Figure 6-3: Gas Flow through T700 with O_3 Generator and Photometer Options during STANDBY 97
Figure 6-4: Gas Flow through Basic T700 in GENERATE Mode 98
Figure 6-5: Gas Flow through T700 with O_3 Options when Generating Non-O_3 Source Gas 99
Figure 6-6: Gas Flow through T700 with O_3 Options when Generating O_3 99
Figure 6-7: Gas Flow through T700 with O_3 Options when in GPT Mode 107
Figure 6-8: Gas Flow through T700 with O_3 Options when in GPTPS Mode 110
Figure 6-9: Gas Flow through T700 with O_3 Options when in PURGE mode 112
Figure 6-10: T700 the TEST CHANNEL Connector 142
Figure 6-11: Setup for Calibrating the TEST CHANNEL 152
Figure 7-1: Default Pin Assignments for Back Panel COMM Port Connectors (RS-232 DCE & DTE) 168
Figure 7-2: Default Pin Assignments for CPU COMM Port Connector (RS-232). 169
Figure 7-3: Location of JP2 on RS232-Multi-drop PCA (Option 62) 182
Figure 7-4: RS-232 Multi-drop PCA Host/Calibrator Interconnect Diagram 183
Figure 7-5: CPU Card Locations of RS-232/485 Switches, Connector 184

Figure 7-6: Back Panel connector Pin-Outs for COM2 in RS-485 Mode 185
Figure 7-7: CPU Connector Pin-Outs for COM2 in RS-485 Mode 185
Figure 7-8: APICOM Remote Control Program Interface........ 192
Figure 8-1: Location of MFC Outlet Ports........ 196
Figure 8-2: Set up for Verifying Optional O_3 Photometer 198
Figure 8-3: External Photometer Validation Setup – Direct Connections 200
Figure 8-4: External Photometer Validation Setup with Calibration Manifolds........ 201
Figure 8-5: O_3 Generator Calibration Setup – Direct Connections........ 206
Figure 8-6: Pressure Monitor Points – T700 – Basic Unit 214
Figure 8-7: Pressure Monitor Points – T700 with O_3 Options and Multiple Cal MFC's Installed 214
Figure 9-1: Location of Gas Flow Control Assemblies for T700's with O_3 Options Installed 222
Figure 9-2: Flow Control Assembly & Critical Flow Orifice........ 223
Figure 9-3: T700 Electronic Block Diagram........ 225
Figure 9-4: T700 CPU Board Annotated 227
Figure 9-5: Relay PCA........ 228
Figure 9-6: Heater Control Loop Block Diagram. 229
Figure 9-7: Status LED Locations – Relay PCA........ 230
Figure 9-8: Status LED Locations – Valve Driver PCA 231
Figure 9-9: T700 Power Distribution Block diagram........ 234
Figure 9-10: Front Panel Display Interface Block Diagram 235
Figure 9-11: Schematic of Basic Software Operation 236
Figure 9-12: O_3 Generator Internal Pneumatics........ 237
Figure 9-13: O_3 Generator Valve and Gas Fixture Locations........ 238
Figure 9-14: O_3 Generator – Electronic Block Diagram 239
Figure 9-15: O_3 Generator Electronic Components Location........ 240
Figure 9-16: O_3 Generator Temperature Thermistor and DC Heater Locations 241
Figure 9-17: O_3 Photometer Gas Flow – Measure Cycle........ 244
Figure 9-18: O_3 Photometer Gas Flow – Reference Cycle 244
Figure 9-19: O_3 Photometer Absorption Path........ 245
Figure 9-20: O_3 Photometer Layout – Top Cover Removed 246
Figure 9-21: O_3 Photometer Electronic Block Diagram........ 247
Figure 10-1: Bypassing the Photometer Sensor PCA and Pump 251
Figure 10-2: Gas Port Setup for Auto-Leak Check Procedure........ 252
Figure 10-3: Gas Flow for Auto-Leak Check Procedure of Base Model T700's 253
Figure 10-4: Gas Flow for Auto-Leak Check Procedure of T700's with Optional Photometer........ 253
Figure 10-5: Photometer Assembly – Lamp Adjustment / Installation 257
Figure 10-6: O_3 Generator Temperature Thermistor and DC Heater Locations 258
Figure 10-7: Location of O_3 Generator Reference Detector Adjustment Pot 258
Figure 11-1: Example of Signal I/O Function 269
Figure 11-2: CPU Status Indicator........ 271
Figure 11-3: Relay PCA Status LEDS Used for Troubleshooting 272
Figure 11-4: Valve Driver PCA Status LEDS Used for Troubleshooting........ 273
Figure 11-5: Location of DC Power Test Points on Relay PCA 275
Figure 12-1: Triboelectric Charging........ 293
Figure 12-2: Basic Anti-ESD Work Station........ 296

LIST OF TABLES

Table 2-1: T700 Dilution System Specifications........25
Table 2-2: T700 Dilution Electrical and Physical Specifications........25
Table 2-3: T700 Specifications for Optional Ozone Generator 26
Table 2-4: T700 Specifications for Optional O_3 Photometer 26
Table 3-1: Display Screen and Touch Control Description........29
Table 3-2: Rear Panel Description........32
Component 32

Function 32
Table 3-3: Status Output Pin Assignments 38
Table 3-4: T700 Control Input Pin Assignments....38
Table 3-5: T700 Control Input Pin Assignments....40
Table 3-6: NIST Standards for CO_2....42
Table 3-7: NIST Standards for CO 43
Table 3-8: NIST Standards for H_2S 43
Table 3-9: NIST Standards for CH_4....43
Table 3-10: NIST Standards for O_2 43
Table 3-11: NIST Standards for SO_2....43
Table 3-12: NIST Standards for NO 44
Table 3-13: NIST Standards for Propane (C_3H_8)....44
Table 3-14: Possible Warning Messages at Start-Up 52
Table 3-15: T700 Default Gas Types 55
Table 3-16: T700 Units of Measure List 61
Table 5-1: Operating Mode Valve States for T700 Calibrator with Optional O_3 Generator....72
Table 5-2: Operating Mode Valve States for T700 Calibrator with Optional O_3 Generator and Photometer....74
Table 5-3: T700 Gas Flow Rate Options....75
Table 6-1: Test Functions Defined 93
Table 6-2: Calibrator Operating Modes....95
Table 6-3: Status of Internal Pneumatics During STANDBY Mode 96
Table 6-4: Status of Internal Pneumatics During GENERATE Mode....98
Table 6-5: Status of Internal Pneumatics During GENERATE → GPT Mode.... 107
Table 6-6: Status of Internal Pneumatics During GENERATE → GPTPS Mode.... 109
Table 6-7: Internal Pneumatics During Purge Mode 112
Table 6-8: Automatic Calibration SEQUENCE Set Up Attributes 115
Table 6-9: Calibration SEQUENCE Step Instruction.... 116
Table 6-10: Sequence Progress Reporting Mode.... 125
Table 6-11: Password Levels 140
Table 6-12: DIAG – Analog I/O Functions.... 142
Table 6-13: Test Channels Functions available on the T700's Analog Output.... 144
Table 6-14: Analog Output Voltage Range Min/Max.... 146
Table 6-15: Voltage Tolerances for the TEST CHANNEL Calibration 152
Table 6-16: Variable Names (VARS).... 155
Table 7-1: COMM Port Communication Modes.... 172
Table 7-2: Terminal Mode Software Commands 176
Table 7-3: Teledyne API Serial I/O Command Types.... 177
Table 7-4: Ethernet Status Indicators 186
Table 7-5: LAN/Internet Configuration Properties.... 187
Table 8-1: Examples of MFC Calibration Points.... 195
Table 8-2: T700 Pressure Sensor Calibration Setup 213
Thirteen LEDs are located on the calibrator's relay PCA to indicate the status of the calibrator's heating zones and some of its valves as well as a general operating watchdog indicator..... 229
Table 9-1: Relay PCA Status LEDs 230
Table 9-2: T700 Photometer Measurement / Reference Cycle 243
Table 10-1: T700 Maintenance Schedule.... 250
Table 11-1: Front Panel Warning Messages 265
Table 11-2: Test Functions – Indicated Failures.... 267
Table 11-3: Test Channel Outputs as Diagnostic Tools 270
Table 11-4: Relay PCA Watchdog LED Failure Indications.... 271
Table 11-5: Relay PCA Status LED Failure Indications.... 272
Table 11-6: Valve Driver Board Watchdog LED Failure Indications.... 273
Table 11-7: Relay PCA Status LED Failure Indications.... 273
Table 11-8: DC Power Test Point and Wiring Color Codes.... 275
Table 11-9: DC Power Supply Acceptable Levels 276
Table 11-10: Relay PCA Control Devices 277
Table 11-11: Analog Output Test Function – Nominal Values Voltage Outputs.... 281

Table 11-12: Status Outputs Check 281
Table 11-13: T700 Control Input Pin Assignments and Corresponding Signal I/O Functions 282
Table 11-14: Control Outputs Pin Assignments and Corresponding Signal I/O Functions Check 283
Table 12-1: Static Generation Voltages for Typical Activities 293
Table 12-2: Sensitivity of Electronic Devices to Damage by ESD 294

LIST OF APPENDICES

APPENDIX A - VERSION SPECIFIC SOFTWARE DOCUMENTATION

APPENDIX A-1: T700 Software Menu Trees, Revision B.7

APPENDIX A-2: T700 Setup Variables Available Via Serial I/O, Revision B.7

APPENDIX A-3: T700 Warnings and Test Measurements via Serial I/O, Revision B.7

APPENDIX A-4: T700 Signal I/O Definitions, Revision B.7

APPENDIX A-5: Model T700 Terminal Command Designators, Revision B.7

APPENDIX B - T700 SPARE PARTS LIST

APPENDIX C - REPAIR QUESTIONNAIRE - T700

APPENDIX D - ELECTRONIC SCHEMATICS

PART I
–
GENERAL INFORMATION

1. INTRODUCTION

1.1. T700 CALIBRATOR OVERVIEW

The Model T700 (typically referred to as T700) is a 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. Up to four gas sources may be used.

The T700 can be equipped with an optional built-in, programmable ozone generator for accurate, dependable ozone calibrations. The T700 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 T700, covering time periods of up to one year. The setup of sequences is simple and intuitive. These sequences 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 T700 design emphasizes fast response, repeatability, overall accuracy and ease of operation. It may be combined with the M701 Zero Air Generator to provide the ultimate in easy to use, precise calibration for your gas calibrators.

Some of the exceptional features of your T700 Dynamic Dilution Calibrator are:

- Advanced T-Series electronics
- LCD Graphical User Interface with capacitive touch screen
- Microprocessor control for versatility
- Bi-directional USB, RS-232, 485 and 100BaseT 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
- 4 calibration gas ports configurable for single or multi-blend gases
- Glass GPT chamber
- Optional Ozone generator and photometer allows use as primary or transfer standard

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2. SPECIFICATIONS AND APPROVALS

2.1. SPECIFICATIONS

Table 2-1: T700 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 cm^3/min – Optional Ranges: 0 to 50 cm^3/min; 0 to 200 cm^3/min
Zero Air Required	10 SLPM @ 30 PSIG Optional: 20 SLPM @ 30 PSIG
CAL gas input ports	4 (configurable)
Diluent Gas Input Ports	1
Response Time	60 Seconds (98%)

Table 2-2: T700 Dilution Electrical and Physical Specifications

Parameter	Specification
Temperature Range	5-40ºC
Humidity Range	0 - 95% RH, non-condensing
Materials	Cal Gas Output Wetted Surfaces: PTFE. Cal Gas Output Manifold: Glass-coated Steel
Dimensions (HxWxD)	7" (178 mm) x 17" (432 mm) x 24" (609 mm)
Operating Altitude	10,000 ft Maximum
Weight	31 lbs (14.06 kg); 39.2 lbs (17.78 kg) including optional photometer, GPT, and 03 generator
AC Power	85VAC to 264VAC 47 Hz to 63Hz
Analog Outputs	1 user configurable output
Analog Output Ranges	0.1 V, 1 V, 5 V or 10 V Range with 5% under/over-range
Analog Output Resolution	1 part in 4096 of selected full-scale voltage (12 bit)
Digital Control Outputs	8 opto-isolated outputs
Digital Control Inputs	12 opto-isolated inputs
Status Outputs	8 opto-isolated outputs
Serial I/O	One (1) RS-232/optional multidrop ; One (1) RS-232/optional RS-485 ; Baud Rate : 300 – 115200 Ethernet: 10Base/100BaseT USB: Two (2) device (Type A), One (1) Com (Type B) optional
Certifications	EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A. IEC 61010-1:90 + A1:92 + A2:95,
Actual Power Draw	At 115V ~ Start up: 110 W, Steady State: 140 W At 230V ~ Start up: 159 W, Steady State: 148 W

Table 2-3: T700 Specifications for Optional Ozone Generator

Parameter	Specification
Maximum Output	6 ppm LPM
Minimum Output	100 ppb LPM
Response Time:	180 Sec. (98%)
Optical Feedback	Standard
Stability (24 hours)	1% of Reading or 1 ppb, whichever is greater (Photometer Feedback Mode)

Table 2-4: T700 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% Full Scale
Rise/Fall Time	<20 sec (photometer response)
Response Time (95%)	180 sec. (system response)
Zero Drift	<1.0 ppb / 7 days
Span Drift	<1% / 24 hours; <2% / 7 days
Minimum Gas Flow Required	800 cc^3/min

2.2. CE MARK COMPLIANCE

EMISSIONS COMPLIANCE

Teledyne API's T700 Dynamic Dilution Calibrator is designed to be fully compliant with:

EN61326 (1997 w/A1: 98) Class A, FCC Part 15 Subpart B Section 15.107 Class A, ICES-003 Class A (ANSI C63.4 1992) & AS/NZS 3548 (w/A1 & A2; 97) Class A.

SAFETY COMPLIANCE

Teledyne API's T700 Dynamic Dilution Calibrator is designed to be fully compliant with:

IEC 61010-1:90 + A1:92 + A2:95,

3. GETTING STARTED

3.1. UNPACKING AND INITIAL SETUP

CAUTION

THE T700 WEIGHS ABOUT 17 KG (40 POUNDS) WITHOUT OPTIONS INSTALLED. TO AVOID PERSONAL INJURY, WE RECOMMEND USING TWO PERSONS TO LIFT AND CARRY THE CALIBRATOR.

CAUTION – Avoid Warranty Invalidation

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

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

NOTE

It is recommended that you store shipping containers/materials for future use if/when the instrument should be returned to the factory for repair and/or calibration serivce. See Warranty section in this manual and shipping procedures on our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

CAUTION

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

1. Inspect the received packages for external shipping damage. If damaged, please advise the shipper first, then Teledyne API.

2. Included with your calibrator is a printed record of the final performance characterization performed on your instrument at the factory. This record, titled *Final Test and Validation Data Sheet* (P/N 05731) is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

3. Carefully remove the top cover of the calibrator and check for internal shipping damage.

   - Remove the locking screw located in the top, center of the Front panel.
   - Remove the two screws fastening the top cover to the unit (one per side towards the rear).
   - Slide the cover backwards until it clears the calibrator's front bezel.
   - Lift the cover straight up.

4. Inspect the interior of the instrument to ensure all circuit boards and other components are in good shape and properly seated.

5. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure they are firmly and properly seated.

6. Verify that all of the optional hardware ordered with the unit has been installed. These are checked on the paperwork accompanying the calibrator.

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

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

Various rack mount kits are available for this calibrator. See Section 5 of this manual for more information.

3.1.1. CALIBRATOR LAYOUT

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

- plug-in mouse (not included) to be used as an alternative to the thouchscreen interface

- thumb drive (not included) to download updates to instruction software (contact T-API Customer Service for information).

3.1.1.1. Front Panel

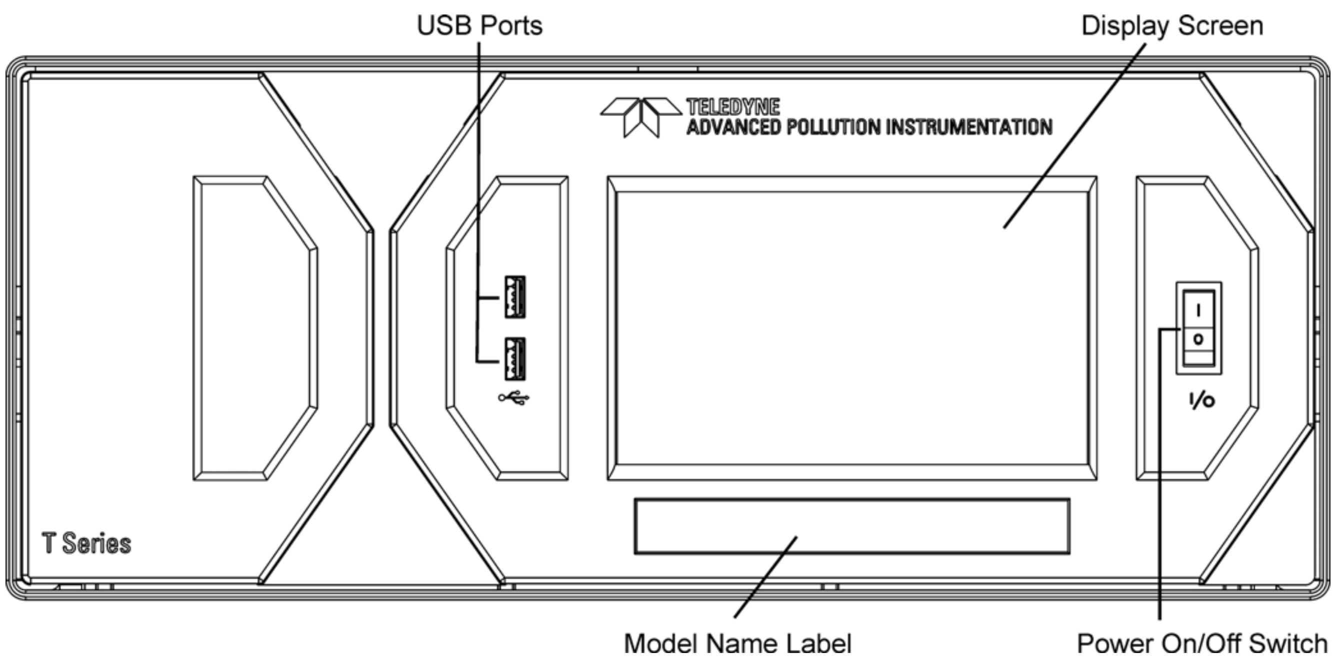


Figure 3-1: T700 Front Panel Layout

Figure 3-2: Display Screen and Touch Control

The front panel liquid crystal display (LCD) screen includes touch control. Upon calibrator start-up, the LCD shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3 2 above (may or may not display a Fault alarm).

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 warning messages, operational data, test function values and response messages 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 front panel display is mapped to the menu charts illustrated in 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.

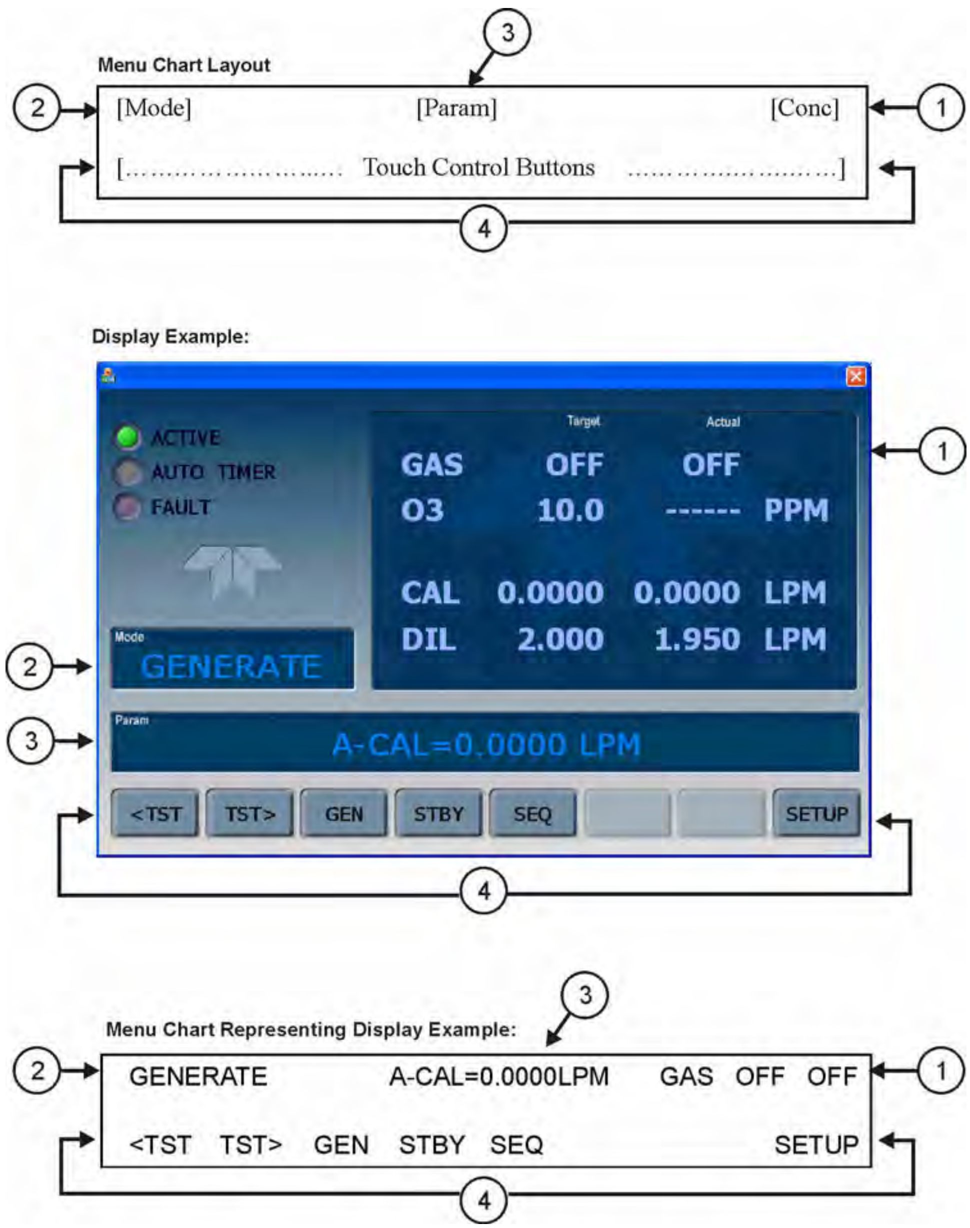


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

3.1.1.2. Rear Panel

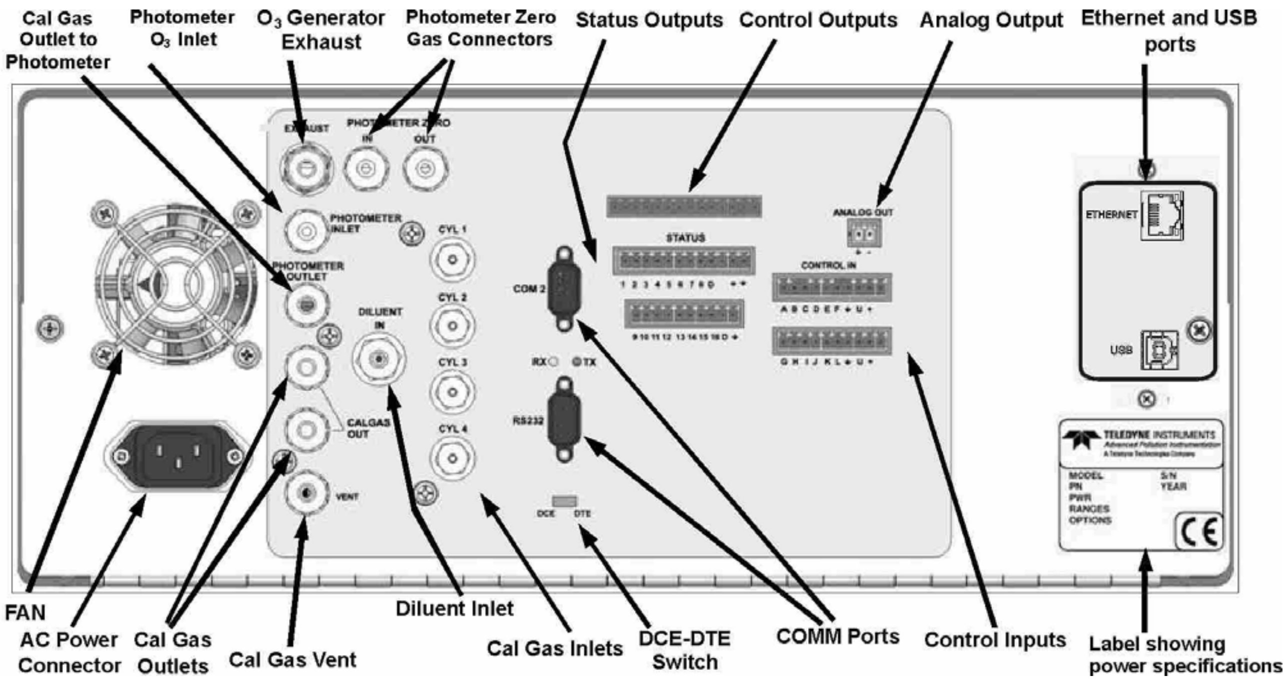


Figure 3-4: T700 Rear Panel Layout

Table 3-2 provides a description of each component on the rear panel.

Table 3-2: Rear Panel Description

Component	Function
Fan	Cools instrument by pulling ambient air into chassis through side vents and exhausting through rear.
AC Power Connector	Connector for three-prong cord to apply AC power to the analyzer **CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the calibrator's rear panel Model number label.**
EXHAUST (option)	Exhaust gas from ozone generator and photometer **CAUTION! Exhaust gas must be vented outside.**
PHOTOMETER ZERO IN (option)	Inlet for photometer Zero Gas
PHOTOMETER ZERO OUT (option)	Outlet for photometer Zero Gas
PHOTOMETER INLET (option)	Measurement gas input for O_3 photometer
PHOTOMETER OUTLET (option)	Calibration gas outlet to O_3 photometer
DILUENT IN	Diluent or zero air gas inlet.
CALGAS OUT	Outlets for calibration gas
VENT	Vent port for output manifold
CYL 1 thru CYL 4	Inlets for up to 4 calibration gases.
COM 2	Serial communications port for RS-232 or RS-485.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication. (Section 7.1.1)
CONTROL OUT	For outputs to devices such as Programmable Logic Controllers (PLCs).
STATUS	For outputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable.
USB	Connector for direct connection to a PC or a laptop computer, using USB cable.
Label w/power specs	Identifies the analyzer model number and lists voltage and frequency specifications

3.1.1.3. Internal Layout

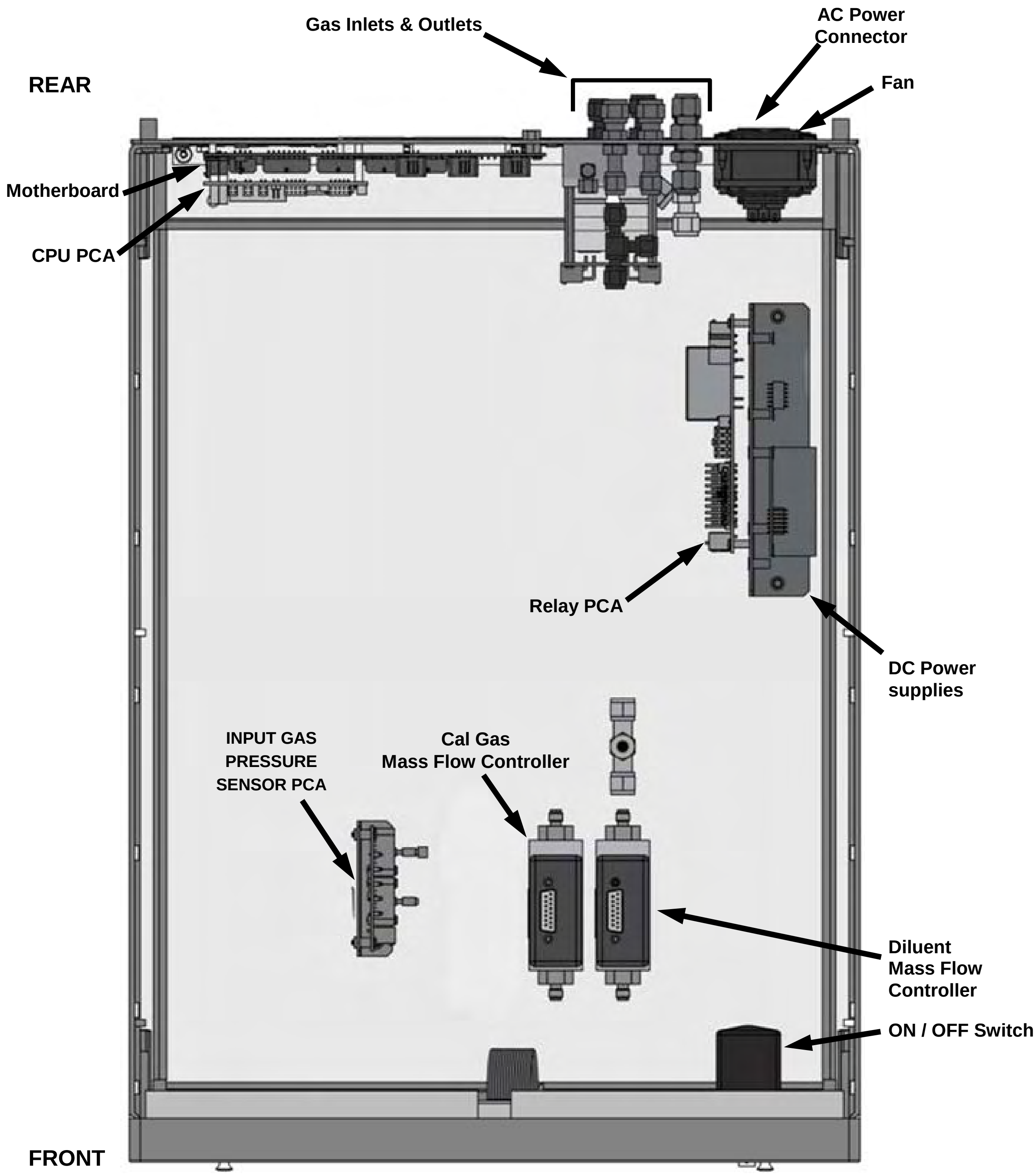


Figure 3-5: T700 Internal Layout – Top View – Base Unit

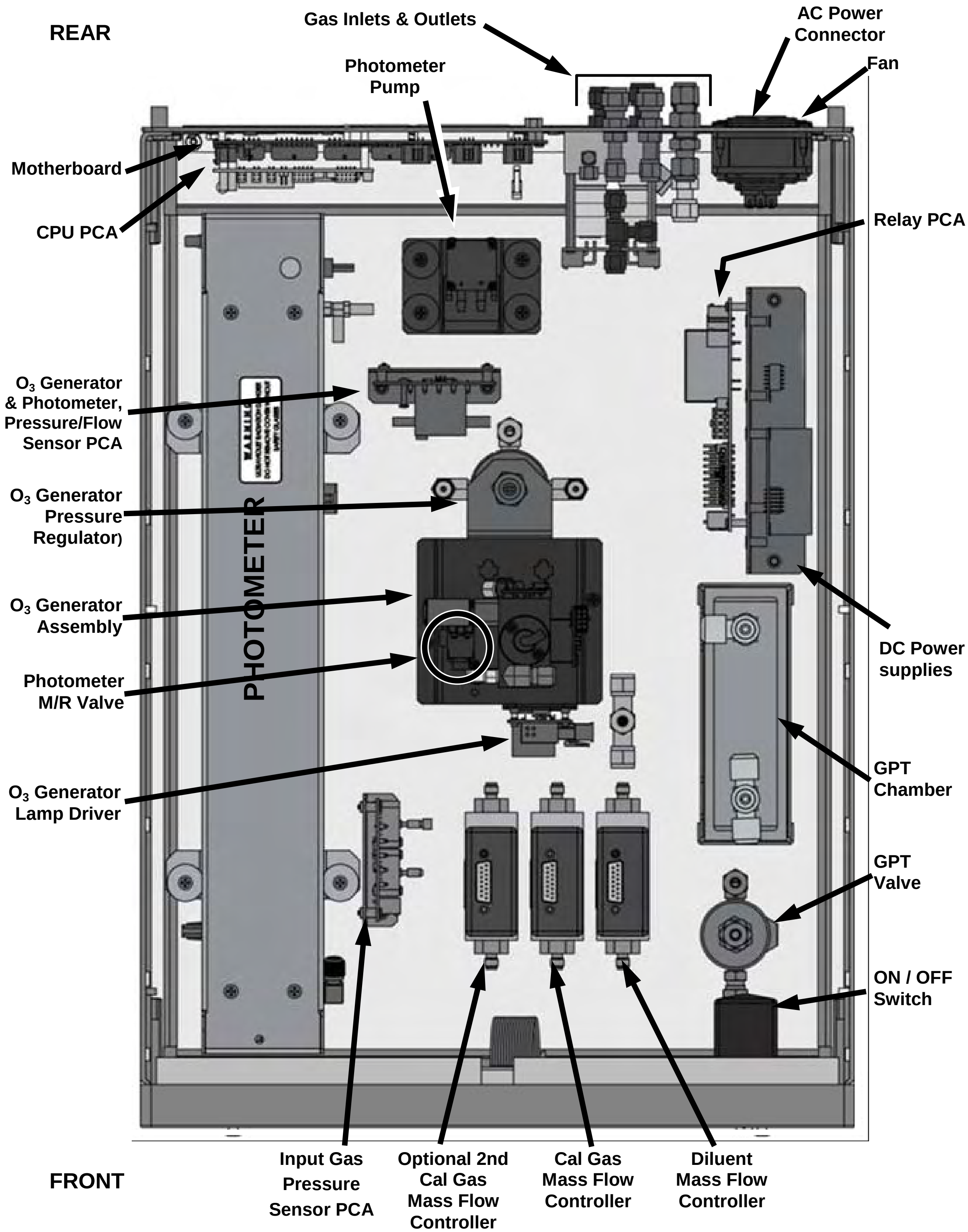


Figure 3-6: T700 Internal Layout – Top View – with Optional O_3 Generator and Photometer

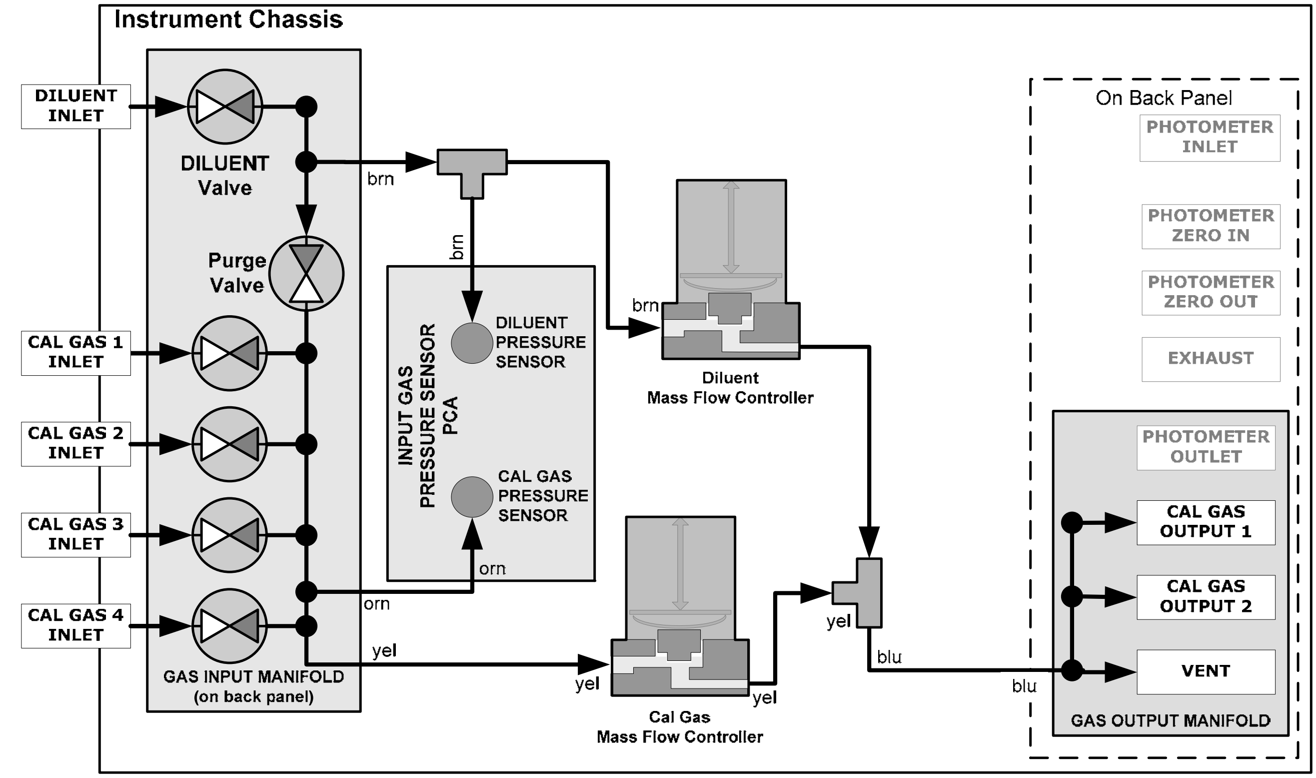


Figure 3-7: T700 Pneumatic Diagram – Base Unit

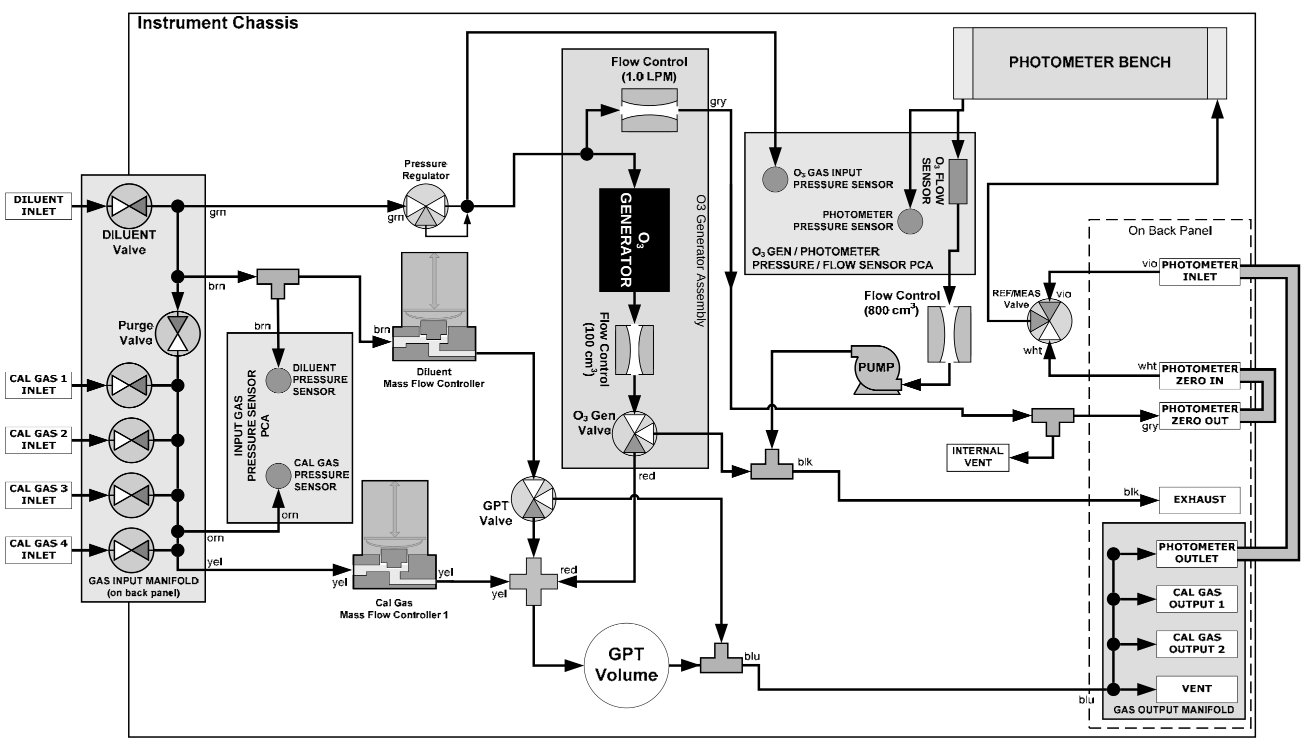


Figure 3-8: T700 Pneumatic Diagram – with O_3 Generator and Photometer

3.1.2. ELECTRICAL CONNECTIONS

3.1.2.1. Power Connection

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

WARNING

HIGH VOLTAGES ARE PRESENT INSIDE THE CALIBRATORS CASE.

POWER CONNECTION MUST HAVE FUNCTIONING GROUND CONNECTION.

DO NOT DEFEAT THE GROUND WIRE ON POWER PLUG.

TURN OFF CALIBRATOR POWER BEFORE DISCONNECTING OR CONNECTING ELECTRICAL SUBASSEMBLIES.

DO NOT OPERATE WITH COVER OFF.

CAUTION

DO NOT LOOK AT THE PHOTOMETER UV LAMP.

UV LIGHT CAN CAUSE EYE DAMAGE.

ALWAYS WEAR GLASSES MADE FROM SAFETY UV FILTERRING GLASS (PLASTIC GLASSES WILL NOT DO).

NOTE

The T700 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.

3.1.2.2. Analog Output Connections

The T700 is equipped with an analog output channel accessible through a connector on the back panel of the instrument. The standard configuration for this output is mVDC. It can be set by the user to output one of a variety of diagnostic test functions (see Section 6.9.1.2).

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

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

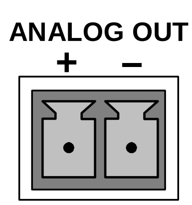


Figure 3-9: T700 Analog Output Connector

3.1.2.3. 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.

NOTE

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 rear panel labeled STATUS. The function of each pin is defined in Table 3-3.

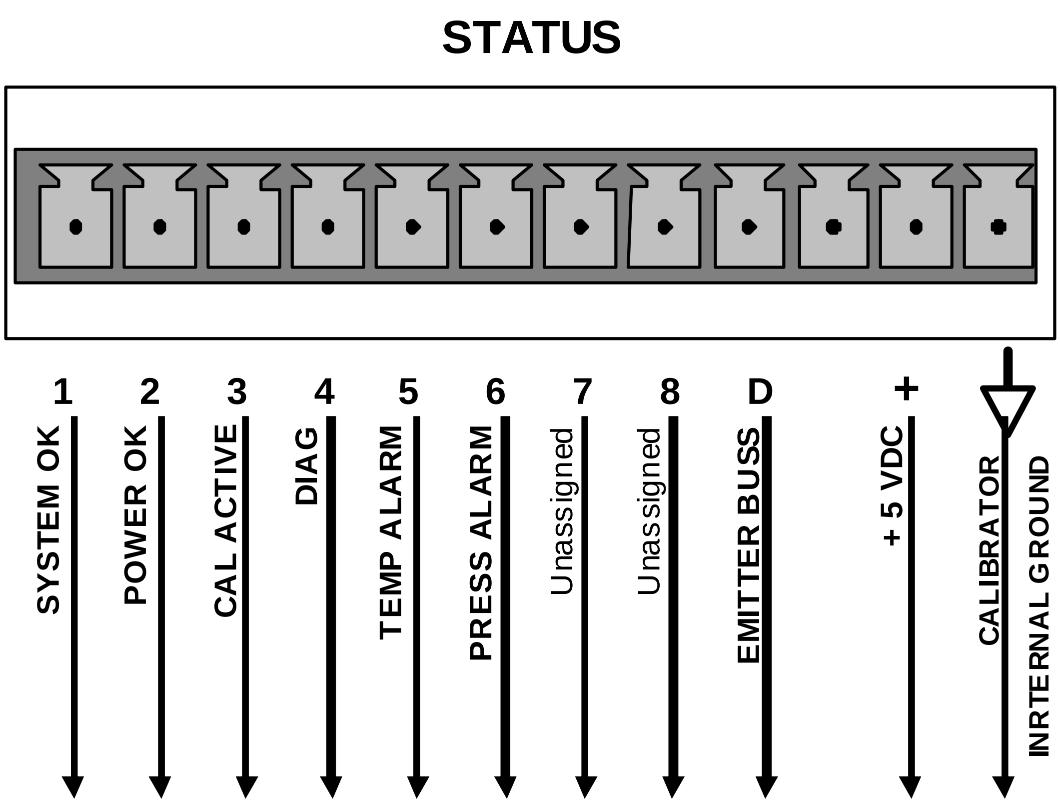


Figure 3-10: Status Output Connector

The pin assignments for the Status Outputs are:

Table 3-3: 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 whenever a temperature alarm is active.
6	**PRESS ALARM**	On whenever gas pressure alarm is active.
7 & 8	Unassigned	
D	Emitter BUS	The emitters of the transistors on pins 1 to 8 are bussed together.
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.
D	Emitter BUS	The emitters of the transistors on pins 9 to 16 are bussed together.
+	DC POWER	+ 5 VDC

3.1.2.4. 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 6.5.1.5 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, that are located on the calibrator's rear panel.

Table 3-4: T700 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 A – F. 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 G – L. 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.

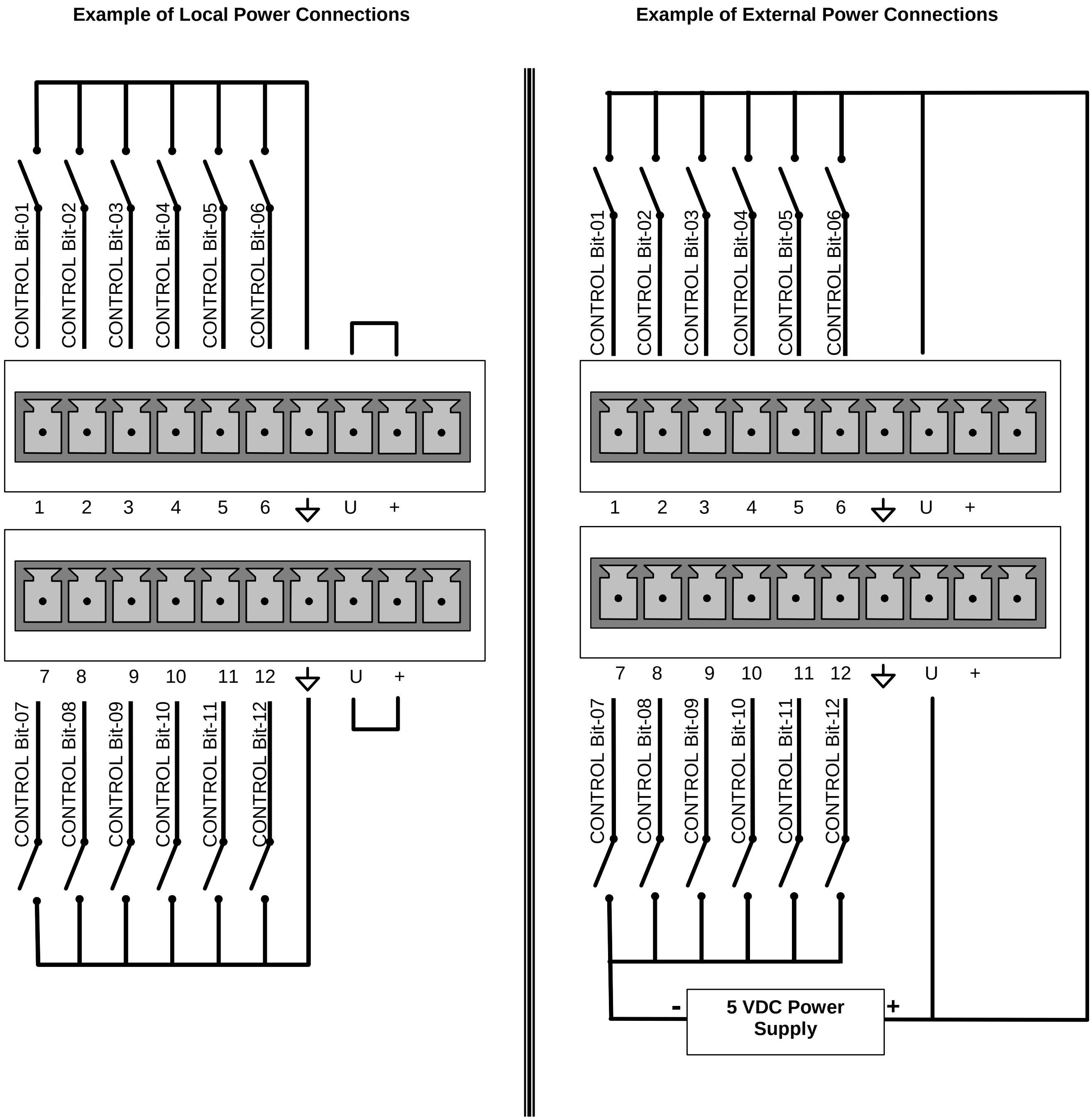


Figure 3-11: T700 Digital Control Input Connectors

3.1.2.5. Connecting the Control Outputs

The calibrator is equipped with 12 opto-isolated, digital control outputs. These outputs are activated by the T700's user-programmable; calibration sequences (see Sections 6.5.1.6 and 6.5.2.8 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 (PLC's), dataloggers, or digital relays/valve drivers.

They are accessed via a 14-pin connector on the calibrator's rear panel (see Figure 3-4).

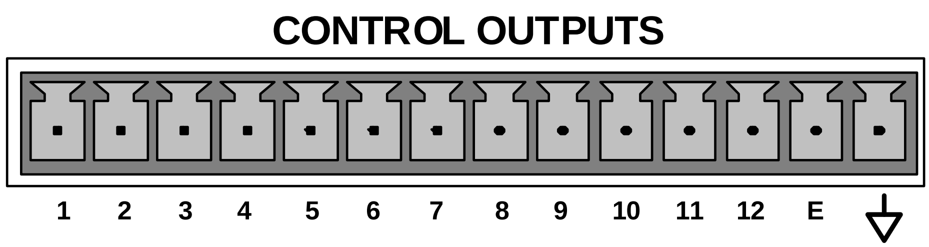


Figure 3-12: T700 Digital Control Output Connector

> **NOTE**
>
> **Most PLC's 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 3-5: T700 Control Input 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 8 are bussed together.
⏚	Digital Ground	The ground level from the calibrator's internal DC power supplies.

3.1.2.6. Connecting the Serial Ports

For R$S-232 or RS-485 communications through the serial interface COMM ports, refer to Section 7 of this manual for instructions on their configuration and usage.

3.1.2.7. Connecting to a LAN or the Internet

For network or Internet communication with the calibrator connect an Ethernet cable (Teledyne API Option 60C) from the Ethernet port on the rear panel to any nearby Ethernet access port.

NOTE

The T700 firmware supports dynamic IP addressing or DHCP (default setup) for remote operation via an Ethernet connection). If your network also supports DHCP, the calibrator will automatically configure its LAN connection appropriately (see Sections 7.1, 7.4 and 7.4.1).

If your network does not support DHCP, or to establish a permanent Ethernet connection, see Section 7.4.1.1 for instructions on manually configuring the connection with a static IP address.

3.1.2.8. Connecting to a PC or Laptop Computer

Fir direct communciation between the analyzer and a PC or a laptop computer connect a USB cable between the analyzer's rear panel USB port and the PC or laptop USB port.

3.1.2.9. Connecting to a Multi-drop Network

If your unit has a Teledyne API's RS-232 multi-drop card (Option 62), see Section 7.2.1 for instructions on setting it up.

3.2. PNENUMATIC CONNECTIONS

3.2.1. 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 calibrator's 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.
- T700 calibrator's 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.

3.2.2. 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.

3.2.2.1. 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 to be 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 3-6: 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 3-7: 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 3-8: 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 3-9: 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 3-10: 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 3-11: 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 3-12: 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 3-13: 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

3.2.2.2. 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.

1. 2SLPM + 2SLPM = 4SLPM
2. 4SLPM x 1.5 = 6SLPM = Total Gas Flow Rate
3. If you set your T700 calibrator 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

4. 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

3.2.3. 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.

3.2.4. CONNECTING CALIBRATION SOURCE GAS TO THE T700 CALIBRATOR

3. Connect the source gas line(s) to the ports labeled **CYL1** through **CYL4** on the back of the calibrator (see Figure 3-4).
   - Source gas delivery pressure should be regulated between 25 PSI to 30 PSI.
   - Use stainless steel tubing with a 1/8 inch outer diameter.

3.2.5. CONNECTING GAS OUTPUTS FROM THE CALIBRATOR

3.2.5.1. Set up for Direct Connections to Other Instruments

Use this setup if you are connecting the T700 calibrator directly to other instruments without the use of any shared manifolds.

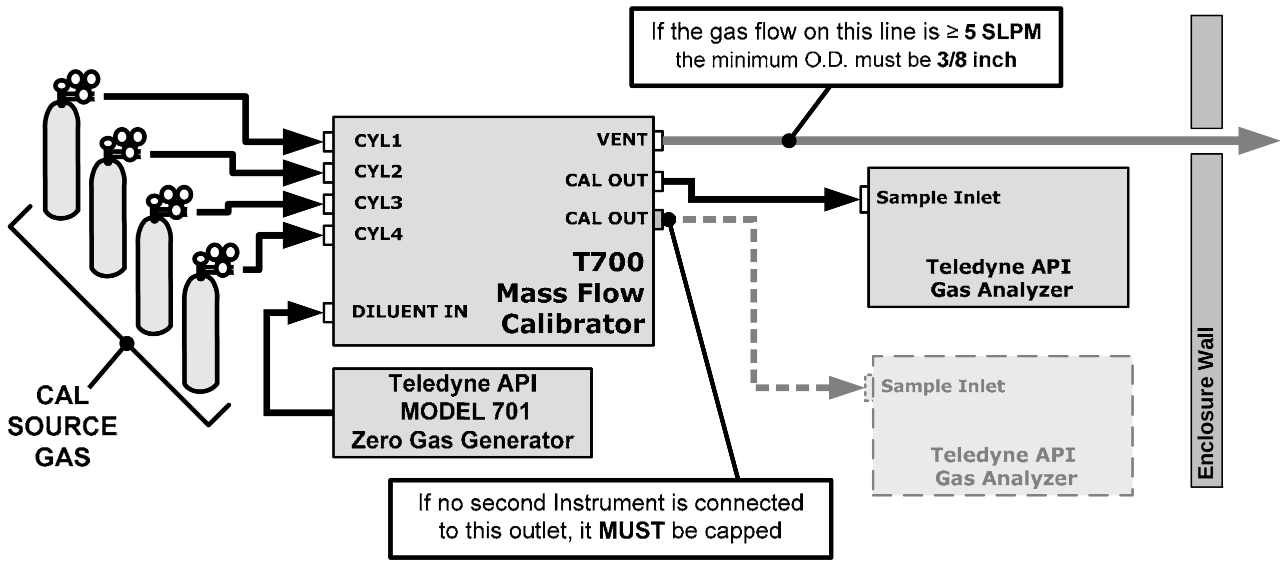


Figure 3-13: Set up for T700 – Connecting the Basic T700 to a Sample Manifold

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 T700 from the TOTAL FLOW setting for the calibrator (see Section 3.3.10).

If the T700 has the optional O_3 photometer installed remember that this option requires 800 cc^3/min (0.8 LPM) of additional flow (see Section 3.2.6.2 or Figure 5-2).

EXAMPLE: Your system has two analyzers each requiring 2SLPM of cal gas flow and the T700 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.

3.2.5.2. Connecting the Calibrator to a Sample Gas Manifold

Use this setup when connecting the T700 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 T700.

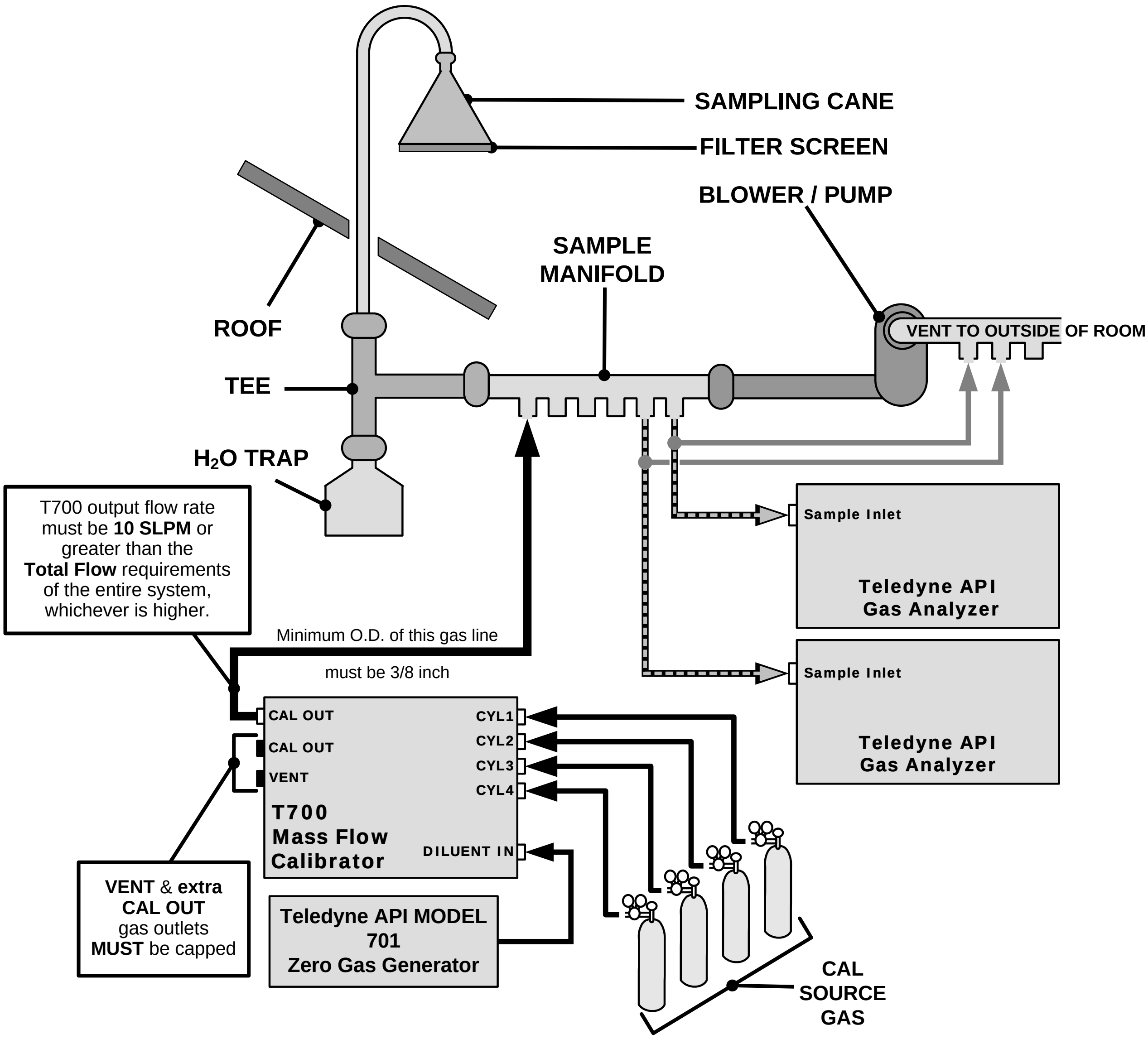


Figure 3-14: Set up for T700 – Connecting the T700 to a Sample Manifold

NOTES

- **This is the recommended method for connecting the T700 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.**

3.2.5.3. 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).

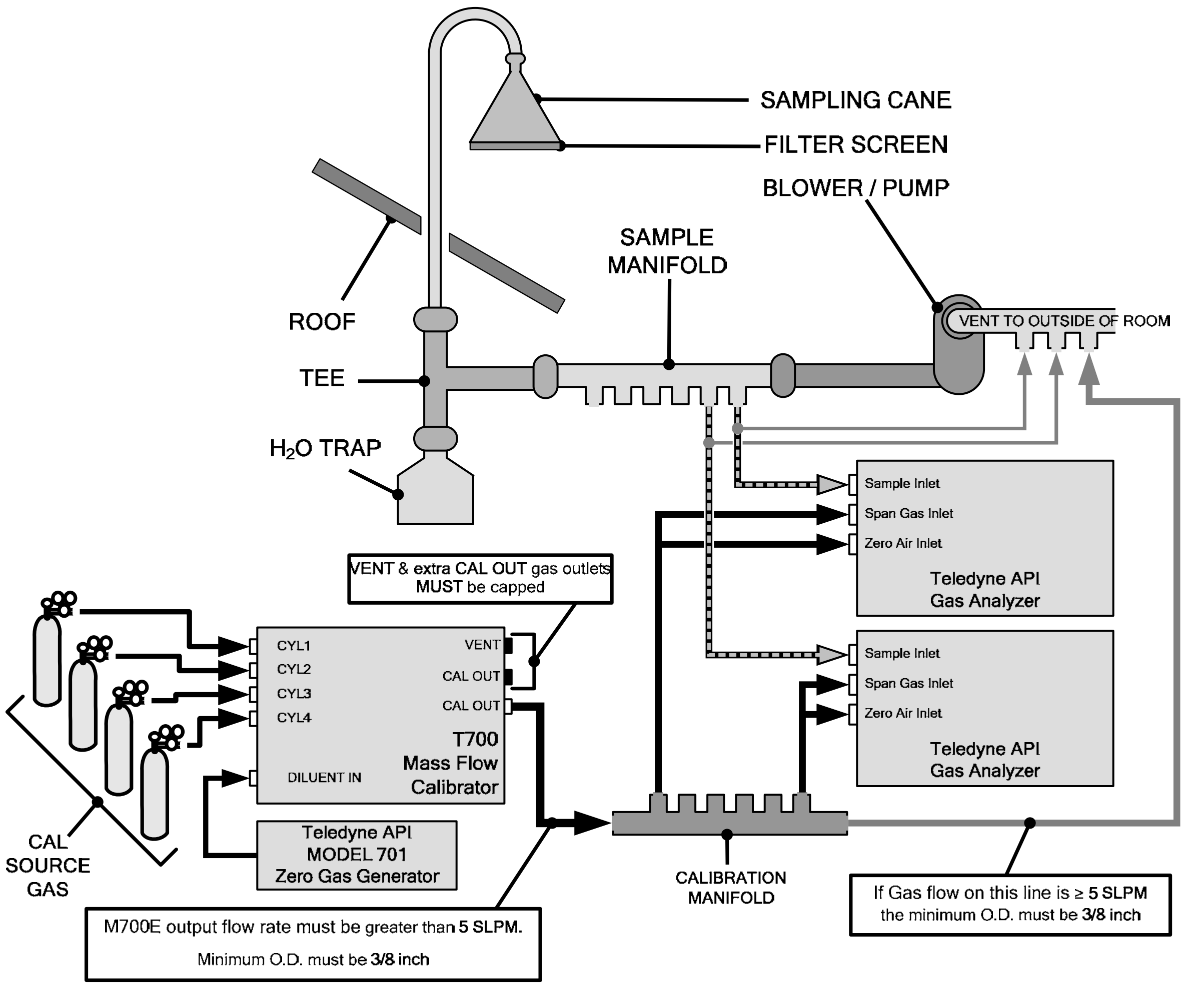


Figure 3-15: Set up for T700 – Connecting the T700 to a Calibration Manifold

NOTES

- **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 <u>upward</u>. <u>All unused ports must be capped</u>.**
- **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.

3.2.5.4. 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 3-16).

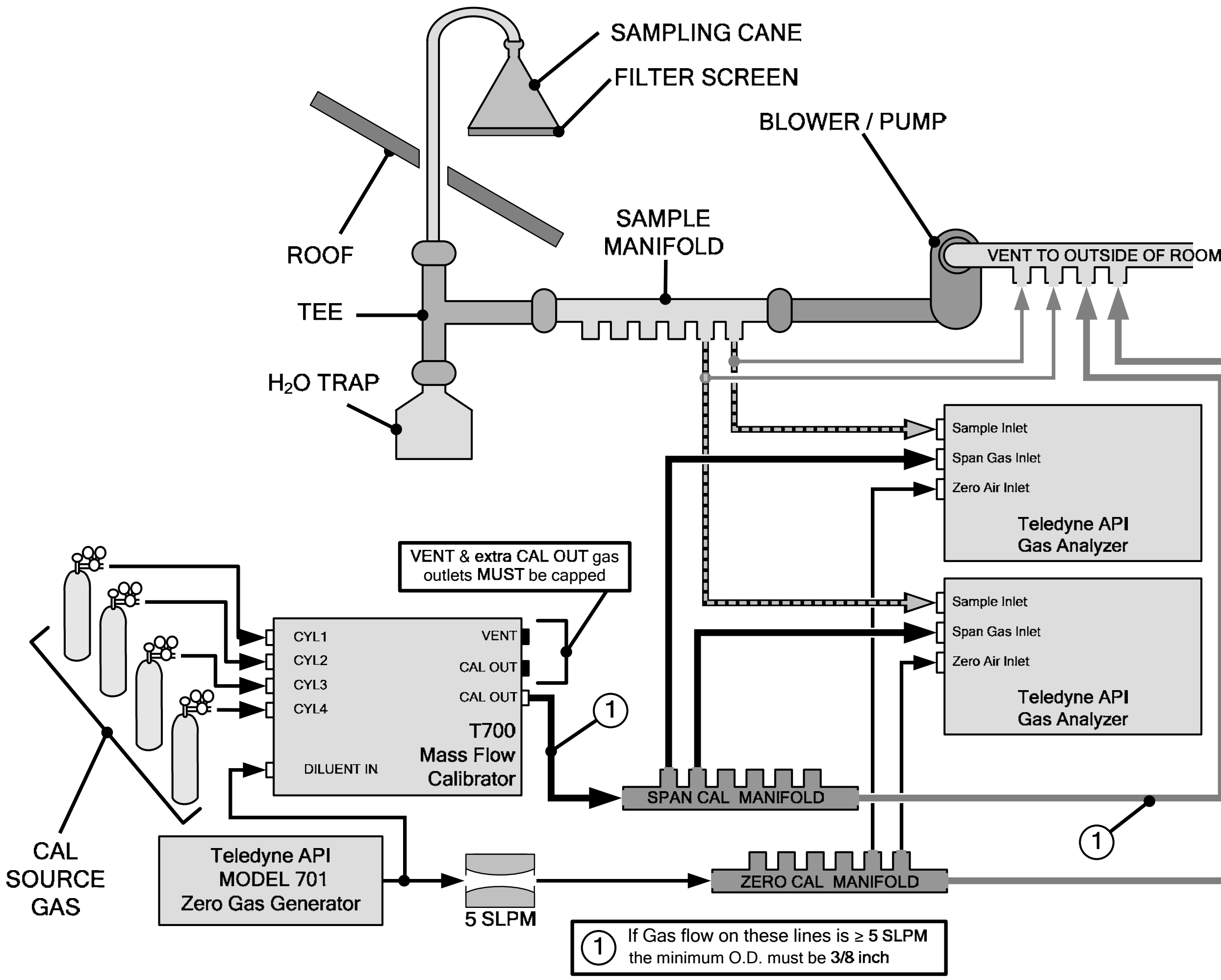


Figure 3-16: Set up for T700 – Connecting the T700 to a Dual Span Gas / Zero Air Manifold

NOTE

This set up is subject to the same notes and conditions as the single calibration manifold described in Section 3.2.5.2 with the following two exceptions:

- **The T700 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 <u>upward</u>. <u>All unused ports must be capped</u>.**

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.

3.2.6. OTHER PNEUMATIC CONNECTIONS

Some of the T700 Dynamic Dilution Calibrator's optional equipment requires additional pneumatic connections.

3.2.6.1. O_3 Generator Option

In addition to the connections discussed in Sections 3.2.3, 3.2.4 and 3.2.5 above, this option also requires an O_3 exhaust line be connected to the **EXHAUST** outlet on the back of the T700 (see Figure 3-4).

NOTE

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

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

3.2.6.2. O_3 Generator with Photometer Option

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" PTEF tubing.

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

3.3. INITIAL OPERATION

If you are unfamiliar with the T700 theory of operation, we recommend that you read Section 9.

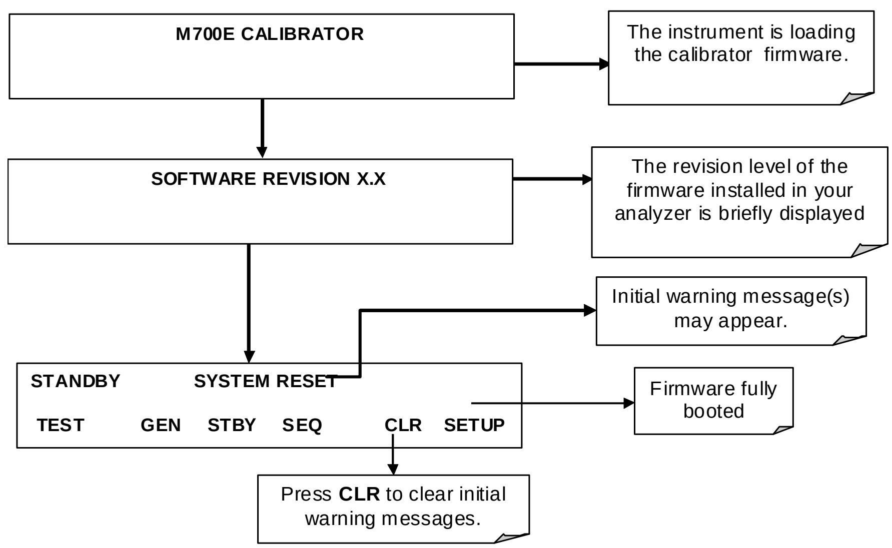
For information on navigating the calibrator's software menus, see the menu trees described in Appendix A.1.

3.3.1. START UP

After all of the electrical and pneumatic connections are made, turn on the instrument. The exhaust fan and should start immediately. If the instrument is equipped with an internal photometer installed, the associated pump should also start up.

The front panel display 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.

Once the CPU has completed this activity, it will begin loading the calibrator firmware and configuration data. During this process, model and software revision information appear briefly in the Param field of the calibrator's front panel display before the firmware is fully booted:



The calibrator should automatically switch to **STANDBY** mode after completing the brief boot-up sequence.

3.3.2. WARM UP

The T700 dynamic dilution 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 front panel display may show messages in the Parameters field. D

3.3.3. 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 11 of this manual.

To view and clear warning messages, press:

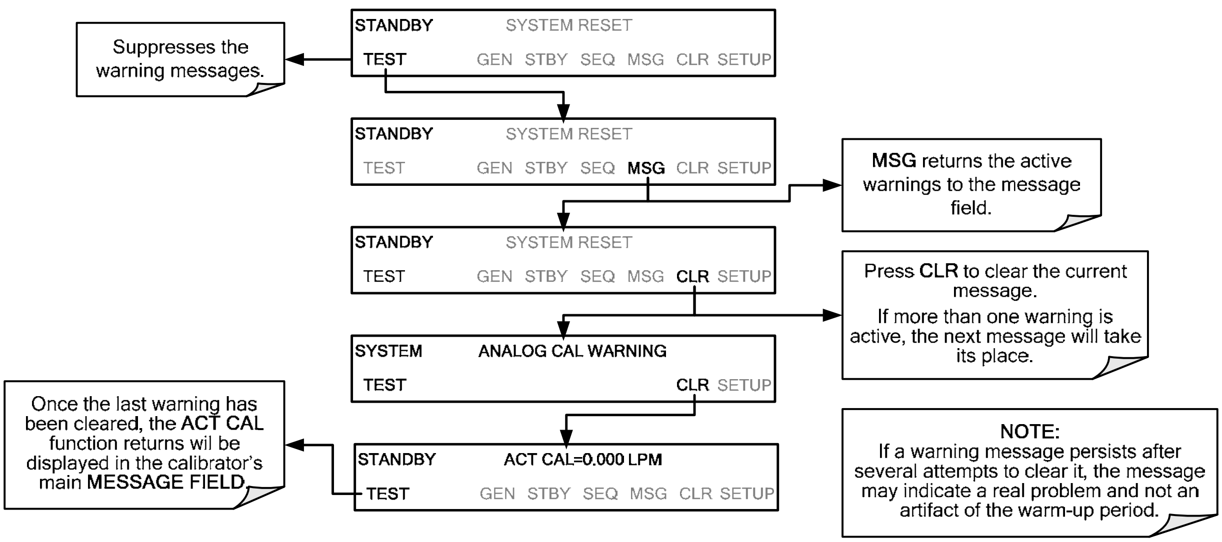


Table 3-14 lists brief descriptions of the warning messages that may occur during start up.

Table 3-14: 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.
FRONT PANEL WARN	The firmware is unable to communicate with the front panel.
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.

MESSAGE	MEANING
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 GEN REFERENCE WARNING[1]	The O_3 generator's reference detector has dropped below the minimum allowable limit.[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 Front Panel Display 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.

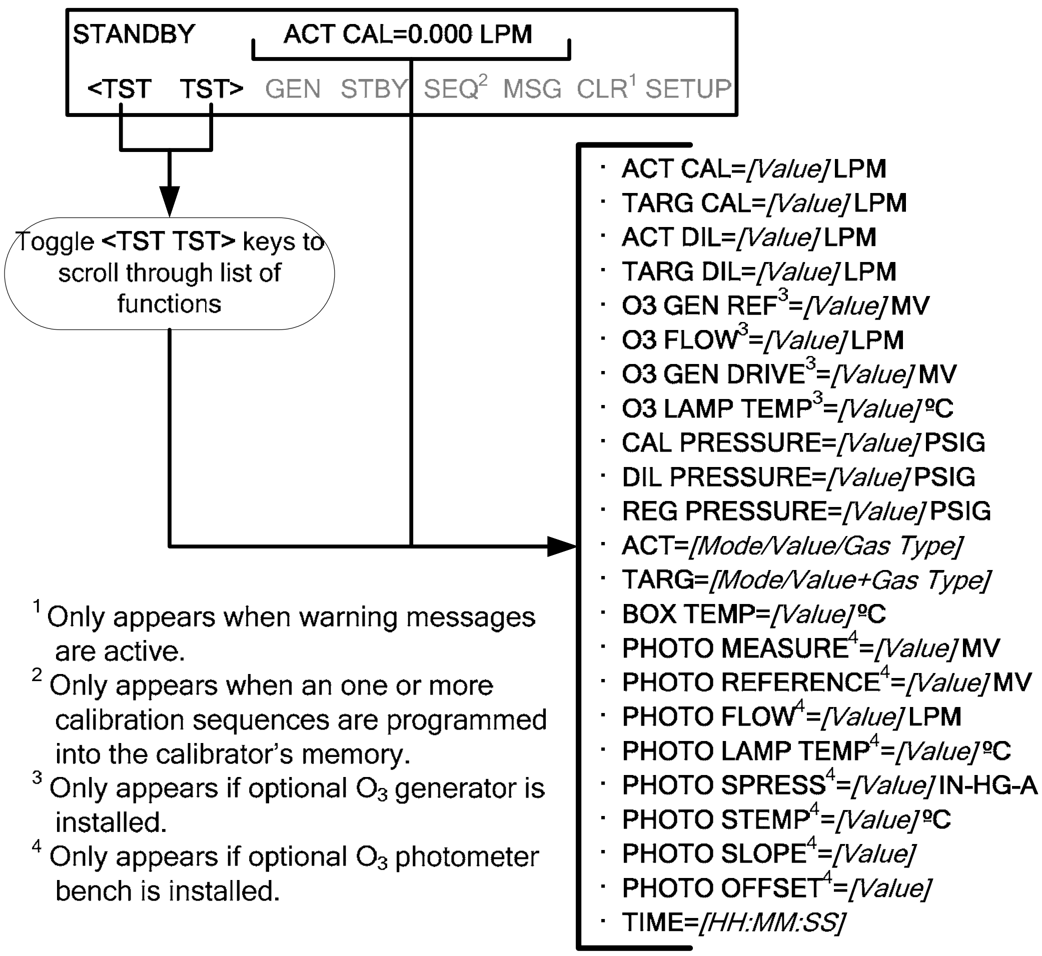
[2] Only applicable for calibrators with the optional photometer installed.

[3] On instrument with multiple Cal Gas MFC's 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).

3.3.4. FUNCTIONAL CHECK

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 front panel as well as their expected values. These functions are also useful tools for diagnosing problems with your calibrator (Section 11.1.2). 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 front panel. Remember until the unit has completed its warm up these parameters may not have stabilized.



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 7.4.1).

   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 7.4.1.1).

3.3.5. SETTING UP THE CALIBRATION GAS INLET PORTS

The T700 Dynamic Dilution 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 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 T700's memory.

3.3.6. DEFAULT GAS TYPES

The T700 calibrator is programmed with the following default gas types corresponding to the most commonly used component gases:

Table 3-15: T700 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 T700.	

3.3.7. USER DEFINED GAS TYPES

3.3.7.1. User Defined Gas Types – General

The T700 calibrator can accept up to four different user defined gases. This allows the use of:

- Less common component gases not included in the T700'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

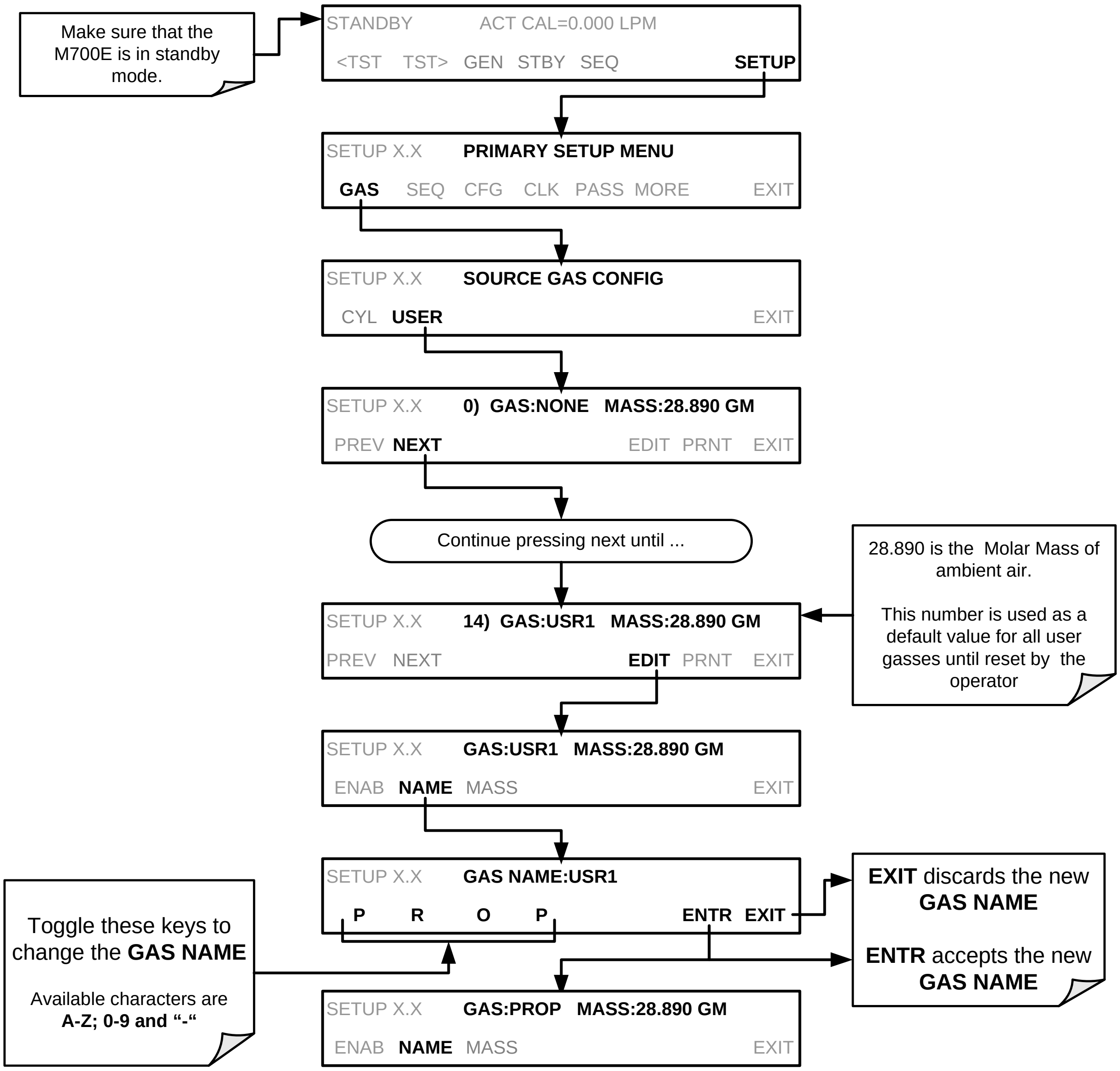
User defined gas names are added to the T700's gas library and will appear as choices during the various calibrator operations along with the default gas names listed in Section 3.3.6.

In its default state, the T700'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.

3.3.7.2. 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, $\mathbf{C_2H_8}$ 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}).**

3.3.7.3. 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.

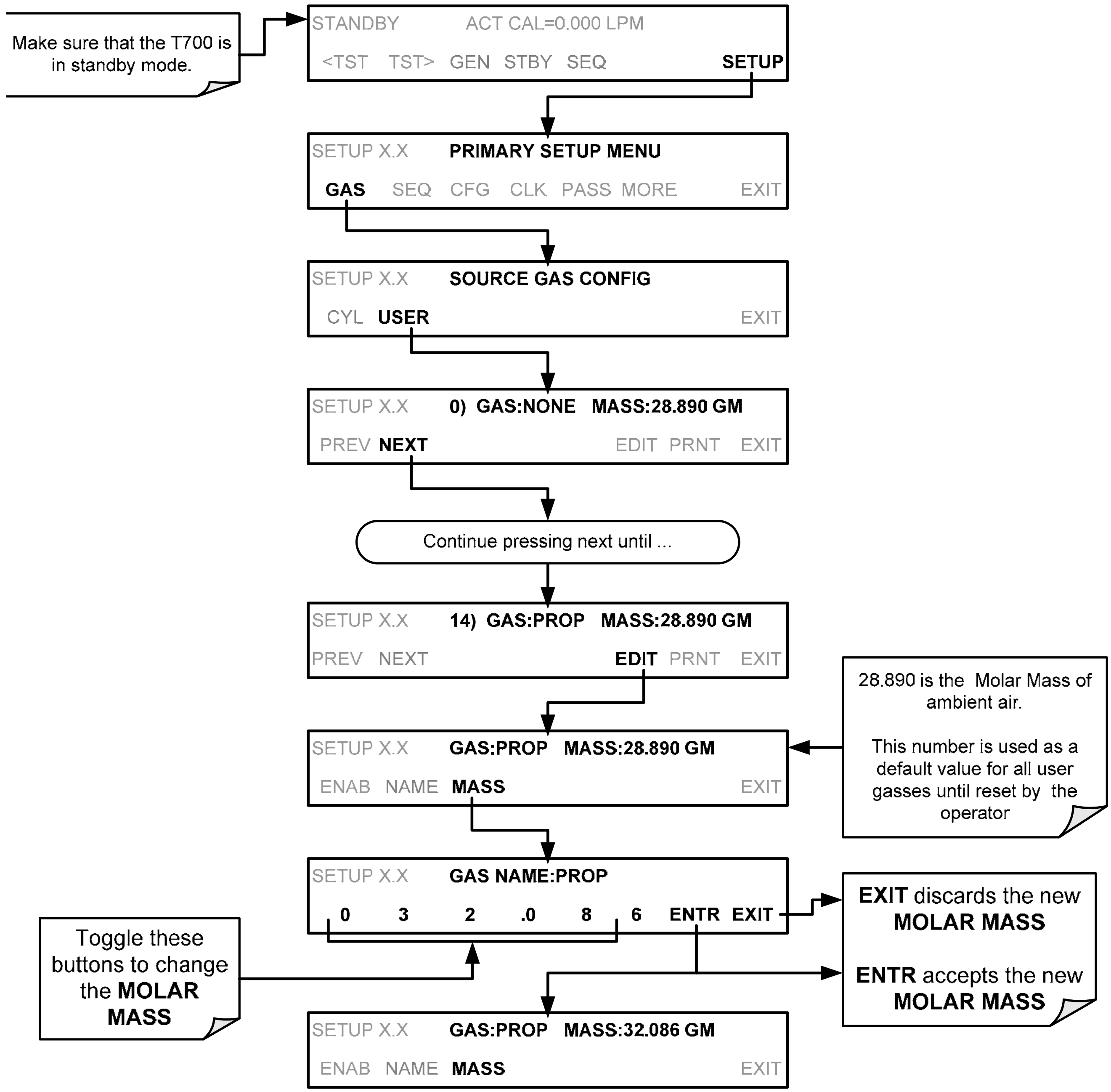
Atomic weights can be found on any Periodic Table of Elements.

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:

$$(12.011 \times 2) + (1.008 \times 8) = 24.022 + 8.064 = \mathbf{32.086}$$

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



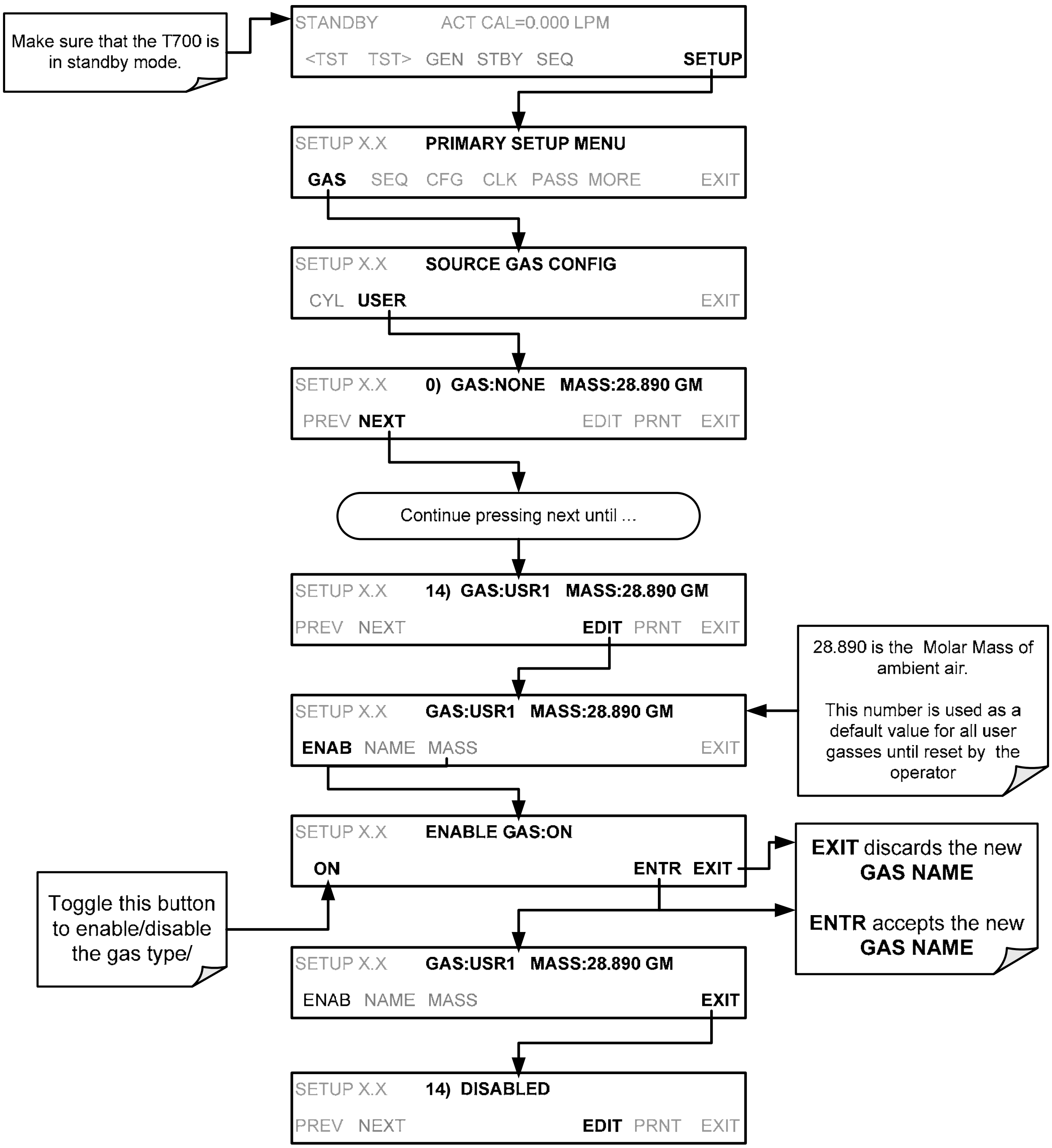
NOTE

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

3.3.7.4. Enabling and Disabling Gas Types

By default, all of the gases listed in Section 3.3.6 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 T700'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:



3.3.8. DEFINING CALIBRATION SOURCE GAS CYLINDERS

3.3.8.1. Setting Up the Ports with Single Gas Cylinders

To program the T700 calibrator's source gas input ports for a single gas cylinder, press:

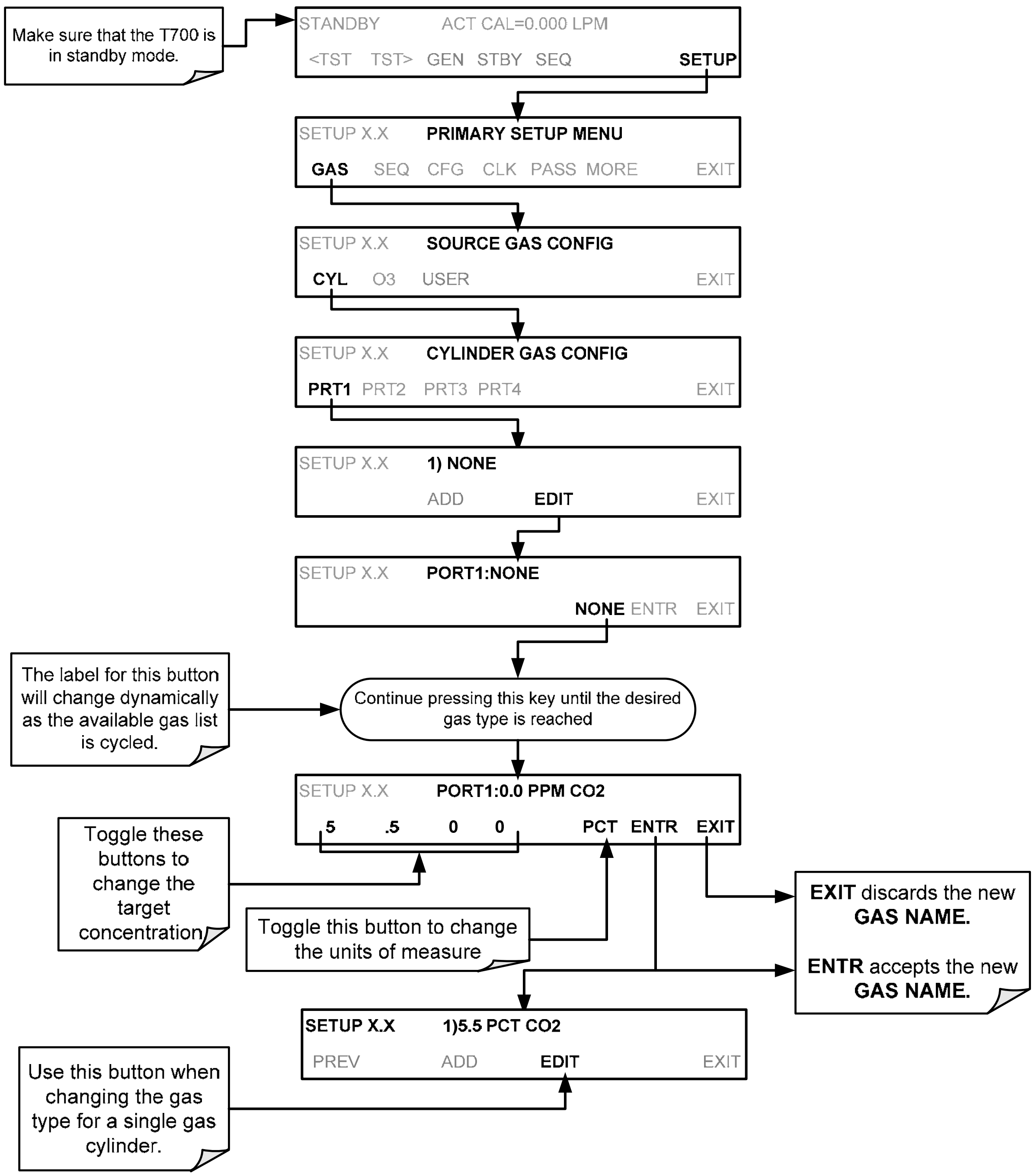


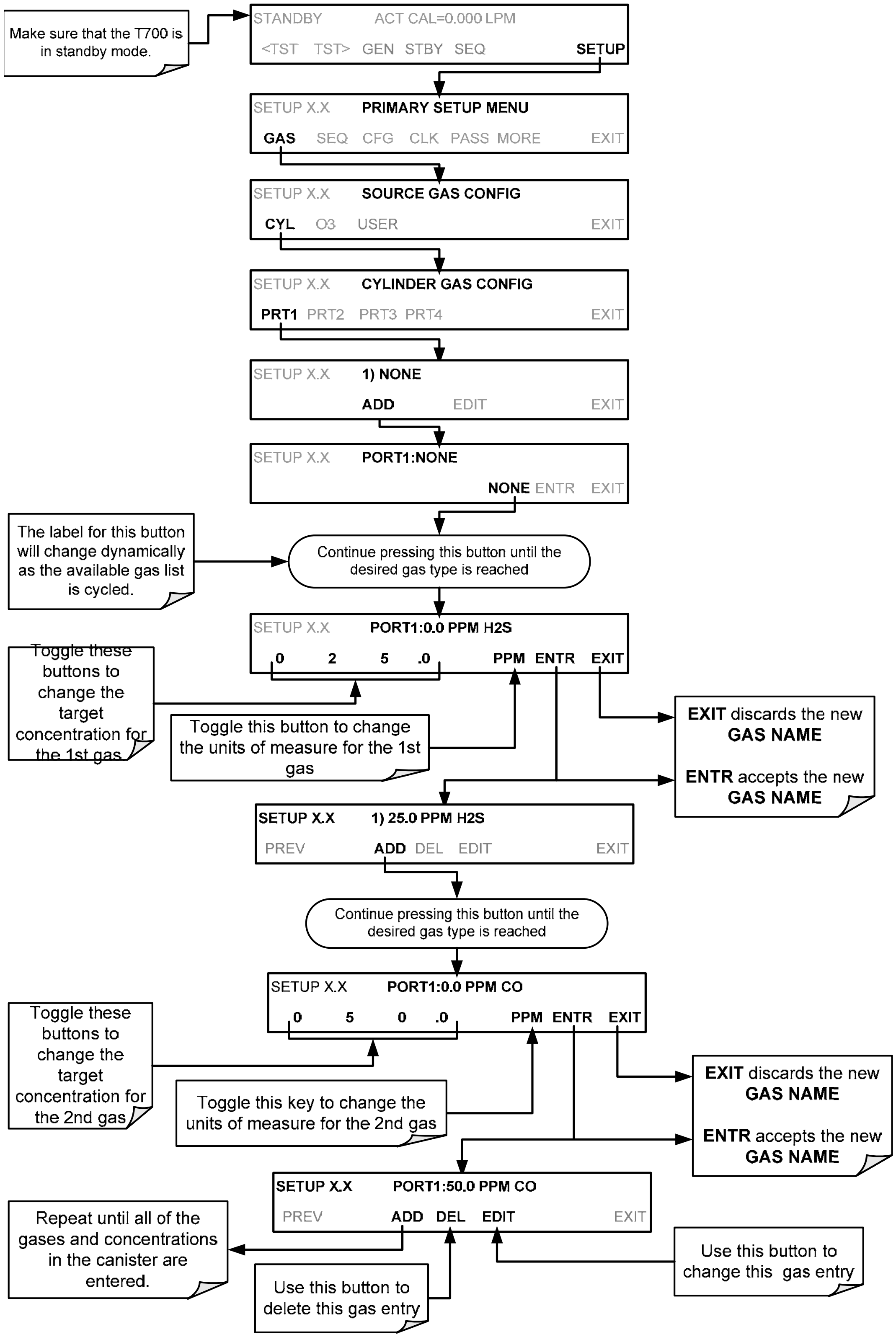
Table 3-16: T700 Units of Measure List

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

Repeat the above steps for each of the T700 calibrator's four gas inlet port. If no gas is present on a particular port, leave it set for the default setting of **NONE.**

3.3.8.2. Setting Up the Ports with Multiple Gas Cylinders

Some applications utilize canisters of source gas that contain more than one component gas. To program a cylinder containing multiple gases, press.



3.3.9. SELECTING AN OPERATING MODE THE O_3 GENERATOR

The O_3 generator can be set to operate in three different modes:

3.3.9.1. 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 T700's CPU in this mode.

3.3.9.2. REF (REFERENCE)

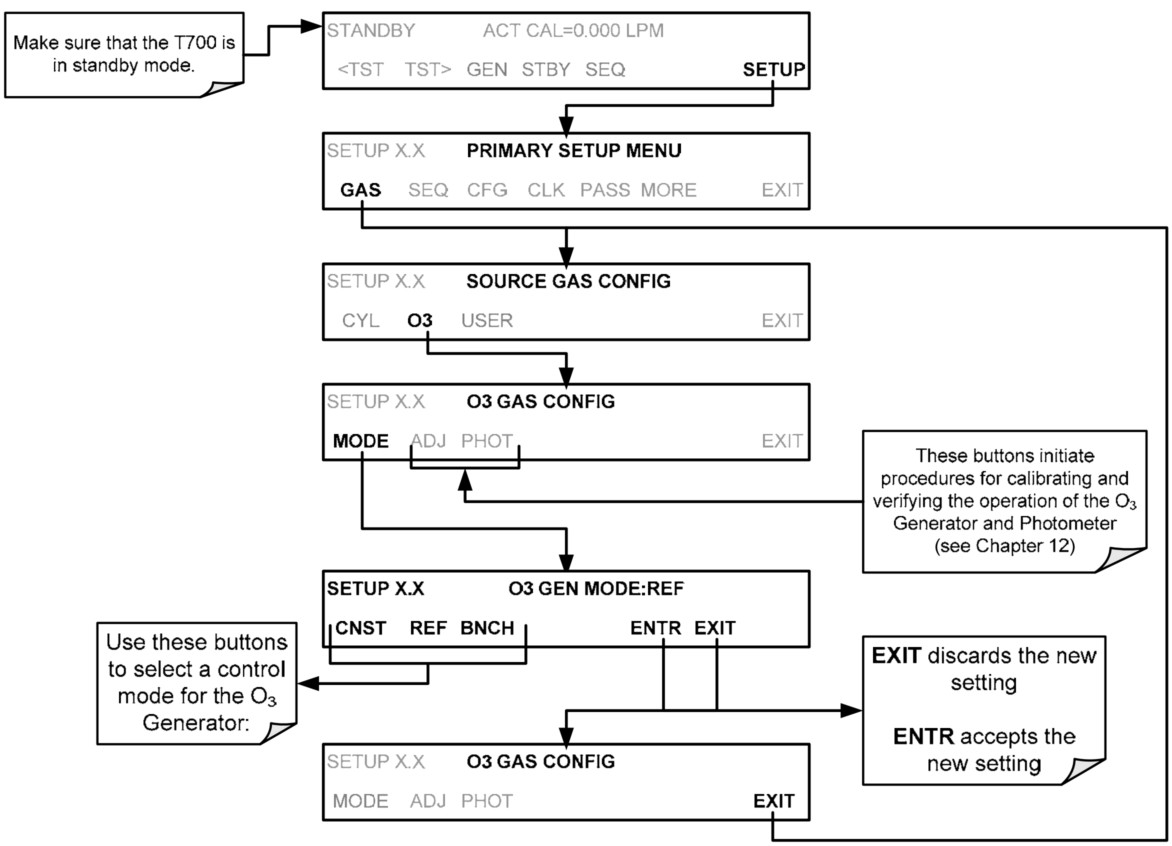
The O_3 control loop will use the generator reference detector's UV lamp measurement as input. This mode does not use the photometer to control the ozone generator.

This setting will be the default mode of the T700 calibrator and will be mused whenever the calibrator is using the **GENERATE → AUTO** command or the **GENERATE** sequence step to create a calibration mixture. When the **GENERATE → MAN** command or the **MANUAL** sequence steps are active, the local O_3 generator mode (chosen during when the command/step is programmed) will take precedence.

3.3.9.3. 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:



3.3.10. SETTING THE T700'S TOTAL GAS FLOW RATE

The default total gas flow rate for the T700 Dynamic Dilution 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 gasses in order to produce calibration mixtures that match the desired output concentrations.

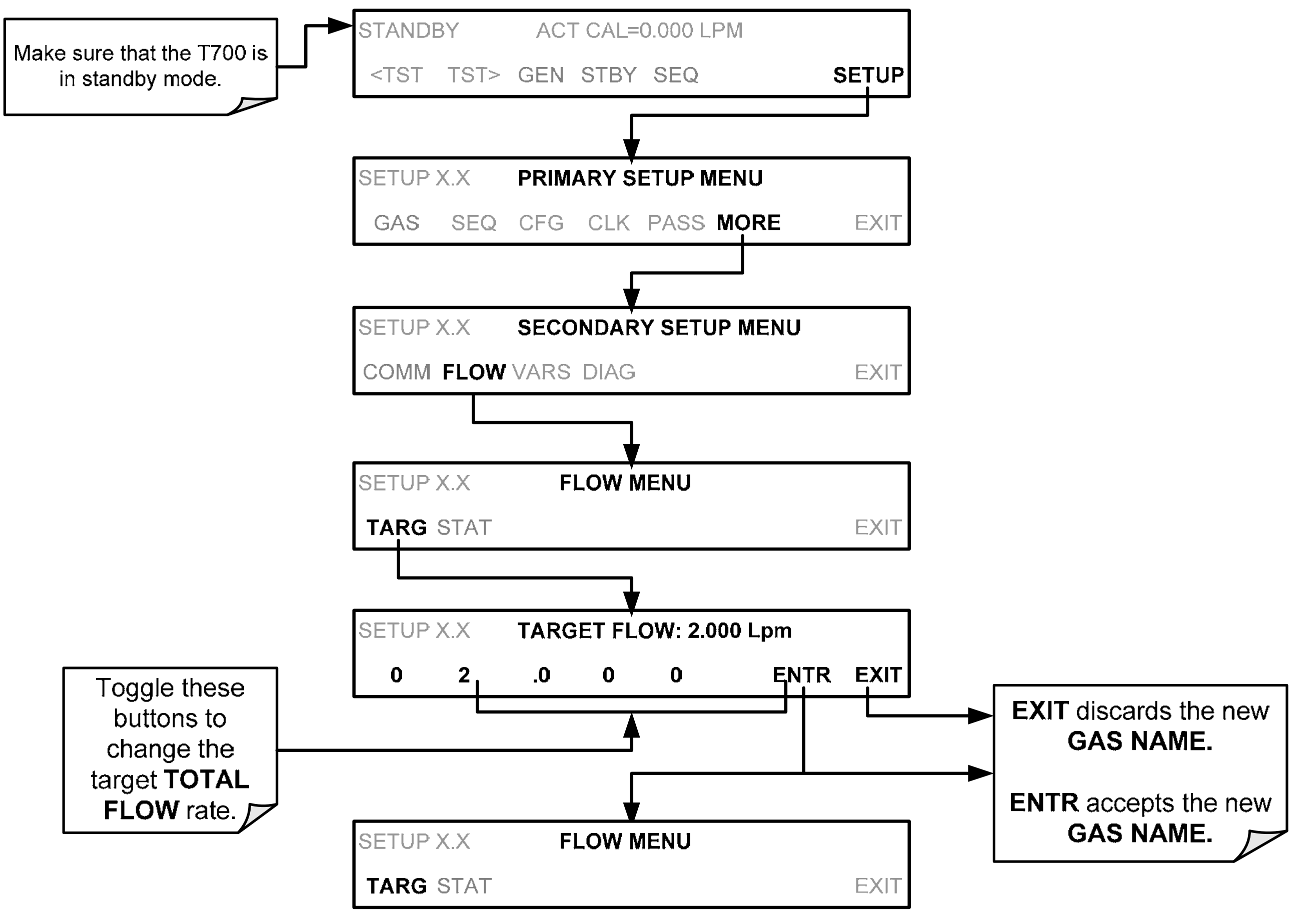
This Total Flow rate may be changed to fit the users' application. Once the flow is changed, then the new flow value becomes the total flow for all the gas concentration generated and recomputes the individual flow rates of the component gases and diluent accordingly.

NOTE

- **The minimum total flow should equal 150% of the flow requirements of all of the instruments to which the T700 will be supplying calibration gas.**
- **Example: If the T700 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 = 7.500 LPM

To set the **TOTAL FLOW** of the of the T700 Dynamic Dilution Calibrator, press:



NOTE

It is not recommended that your 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 6.4.2) or;
- As part of a **GENERATE** step when programming a sequence (see Section 6.5.2.1).

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 6.4.3) or;
- As part of a **MANUAL** step when programming a sequence (see Section 6.5.2.9).

NOTE

When calculating total required flow for T700's with O_3 photometers installed ensure to account for the 800 cc/min flow it requires.

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4. FREQUENTLY ASKED QUESTIONS AND GLOSSARY

4.1. FAQ'S

The following list is a list from the Teledyne API'S Customer Service Department of the 10 most commonly asked questions relating to the T700 Dynamic Dilution Calibrator.

Q: My ozone ACT =XXXX why?

A: 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

Q: When I generate ozone, it takes a long time to settle out or it fluctuates around the number until finally stabilizing.

A: Perform an O_3 Gen Adjust, and then an O_3 Gen Calibration. Re-run points. See Section 8.

Q: Why does the **ENTR** button sometimes disappear on the front panel display?

A: Sometimes the **ENTR** button will disappear if you select a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00.

Once you adjust the setting to an allowable value, the **ENTR** button will re-appear.

Q: How do I make the RS-232 Interface Work?

A: See Section 7.1

Q: When should I change the sintered filter(s) in the calibrators critical flow orifice(s) and how do I change them?

A: The sintered filters do not require regular replacement. Should one require replacement as part of a troubleshooting or repair exercise see Section 11.7.1.

Q: How often should I rebuild the photometer pump on my calibrator?

A: The diaphragm of the photometer pump should be replaced approximately once a year.

Q: How long do the UV lamps of the optional O_3 generator and photometer last?

A: The typical lifetime is about 2-3 years.

4.2. GLOSSARY

Acronym – A short form or abbreviation for a longer term. Often artificially made up of the first letters of the phrase's words.

APICOM – Name of a remote control program offered by Teledyne-API to its customers

ASSY – Acronym for *Assembly.*

cm^3 – metric abbreviation for *Cubic Centimeter*. Same as the obsolete abbreviation "cc".

Chemical formulas used in this document:

- CO_2 – carbon dioxide
- C_2H_8 – propane

- CH_4 – methane
- H_2O – water vapor
- HC – general abbreviation for hydrocarbon
- HNO_3 – nitric acid
- H_2S – hydrogen sulfide
- NO_X – nitrogen oxides, here defined as the sum of NO and NO_2
- NO – nitric oxide
- NO_2 – nitrogen dioxide
- NOy – nitrogen oxides, often called odd nitrogen, the sum of NO, NO_2 (NO_X) plus other compounds such as HNO_3. Definitions vary widely and may include nitrate (NO_3-), PAN, N_2O and other compounds.
- NH_3 – ammonia
- O_2 – molecular oxygen
- O_3 – ozone
- SO_2 – sulfur dioxide

DAS – Acronym for *Data Acquisition System*

DIAG – Acronym for *Diagnostics*, the diagnostic menu or settings of the system

DHCP – Acronym for *Dynamic Host Configuration Protocol.* A protocol used by LAN or Internet servers that automatically sets up the interface protocols between themselves and any other addressable device connected to the network.

DOM – Acronym for *Disk-on-Module*, the system's central storage area for system operating system, firmware and data. This is a solid-state device without mechanical, moving parts that acts as a computer hard disk drive under Windows CE.

EEPROM – also referred to as a FLASH chip.

ESD – Acronym for *Electro-Static Devices*.

FEP – Acronym for Fluorinated Ethylene Propylene polymer, one of the polymers that *du Pont* markets as *Teflon*® (along with PFA and PTFE).

FLASH – flash memory is non-volatile, solid-state memory.

I^2C Bus – read: I-square-C Bus. A serial, clocked serial bus for communication between individual system components

IC – Acronym for *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.

LAN – Acronym for *local area network.*

LED – Acronym for *Light Emitting Diode.*

LPM – Acronym for *Liters Per Minute.*

MFC – Acronym for *Mass Flow Controller*.

MOLAR MASS – The molar mass is 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

PCA – Acronym for *Printed Circuit Assembly*, this is the → PCB with electronic components installed and ready to use

PCB – Acronym for *Printed Circuit Board*, the bare circuit board without components

PLC – Acronym for *Programmable Logic Controller*, a device that is used to control instruments based on a logic level signal coming from the system

PFA – Acronym for *Per-Fluoro-Alkoxy*, an inert polymer. One of the polymers that *du Pont* markets as *Teflon®* (along with FEP and PTFE).

PTFE – Acronym for *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 *Teflon®* (along with FEP and PFA).

PVC – Acronym for *Poly Vinyl Chloride*.

RS-232 – An electronic communication protocol of a serial communications port.

RS-485 – An electronic communication protocol of a serial communications port.

SLPM – Acronym for standard liters per minute; liters per minute of a gas at standard temperature and pressure

TCP/IP – Acronym for *Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices and the Internet

VARS – Acronym for *Variables*, the variables menu or settings of the system

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5. OPTIONAL HARDWARE AND SOFTWARE

This includes a brief description of the hardware and software options available for the T700 Dynamic Dilution Calibrator. For assistance with ordering these options, please contact the Sales department of Teledyne – Advanced Pollution Instruments at:

TOLL-FREE: 800-324-5190
FAX: 858-657-9816
TEL: 858-657-9800
E-MAIL: api-sales@teledyne.com
WEB SITE: www.teledyne-api.com

5.1. OZONE OPTIONS

5.1.1. INTERNAL OZONE GENERATOR (OPT 01A)

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 T700 Dynamic Dilution Calibrator 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, allow the T700 to use the GPT technique to more precisely create NO_2 calibration mixtures

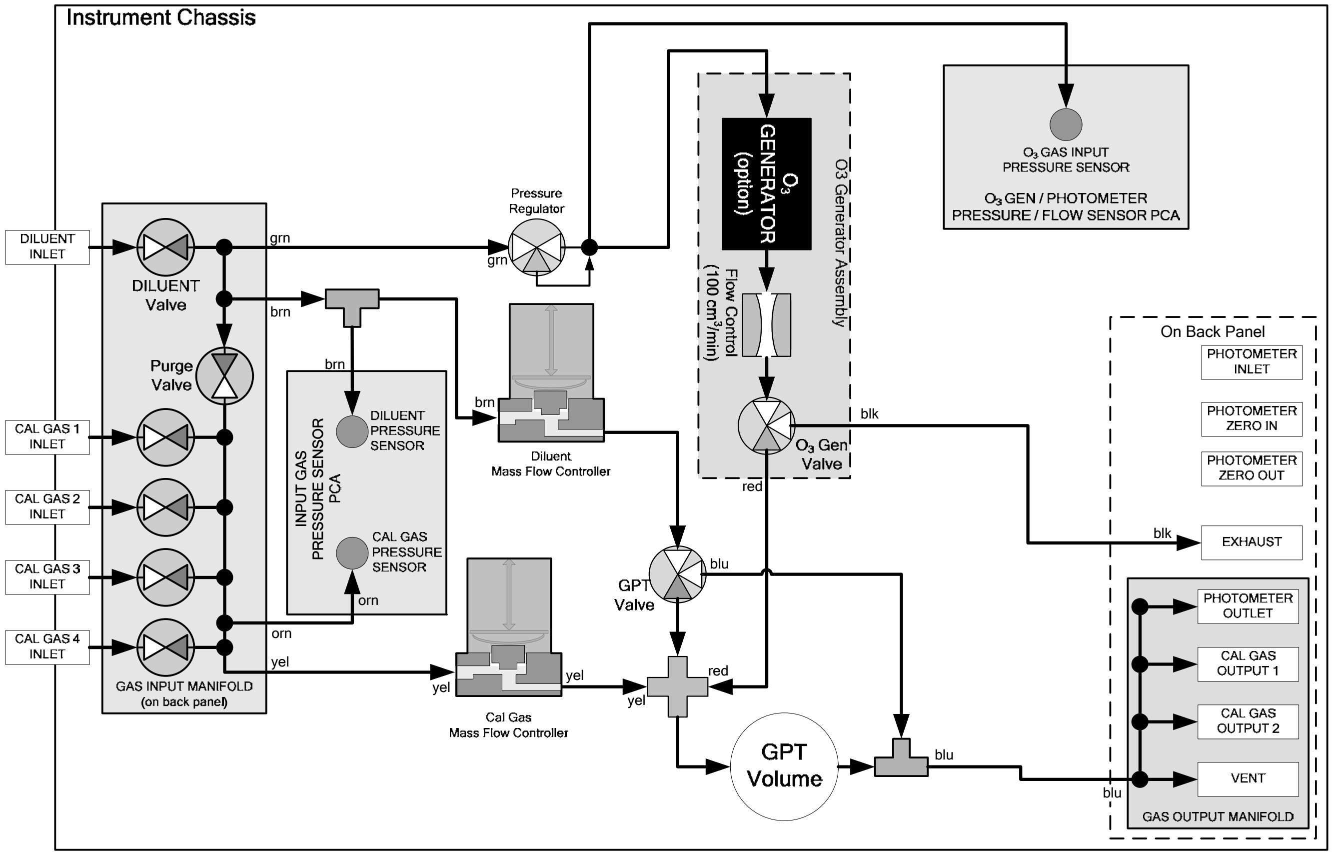


Figure 5-1: Internal Pneumatics for T700 Calibrator with Optional O_3 Generator and GPT Chamber.

Table 5-1: Operating Mode Valve States for T700 Calibrator with Optional O_3 Generator.

MODE	VALVES (X = Closed; O = Open)								MFC's		
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	CAL1	CAL2[1]	DILUENT
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	X	X	ON[3]	ON[3]	ON
Generate O_3	X	X	X	X	X	O	X	O	OFF	OFF	OFF
GPT	O[2]	O[2]	O[2]	O[2]	X	O	O	O	ON[3]	ON[3]	ON
GPTPS	X	X	X	X	X	O	O	O	OFF	OFF	ON
PURGE	X	X	X	X	O	O	O	O	ON[3]	ON[3]	ON
STANDBY	X	X	X	X	X	O	X	X	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 instrument with multiple MFC's 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 one of two ways:

- CONSTANT mode: By selecting a specific, constant drive voltage (corresponding to a specific O_3 concentration) for the generator, or;
- REFERENCE 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 an intensity corresponding to that concentration. The voltage output of a reference detector, also internal to the generator, is digitized and sent to the T700's CPU where it is used as input for a control loop that maintains the intensity of the UV lamp at a level appropriate for the chosen set point.

See Section 9.6 for more details on the operation of the O_3 generator.

5.1.2. UV PHOTOMETER MODULE (OPT 02A)

The photometer option increases the accuracy of the T700 calibrator's optional O_3 generator (**OPT 01A –** see Section 5.1.1) 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 measure 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 T700's CPU based on the actual O_3 concentration measurements made by the photometer.

See Section 9.7 for more details on the operation of the O_3 photometer.

This option requires that the O_3 generator (**OPT 01A**) be installed.

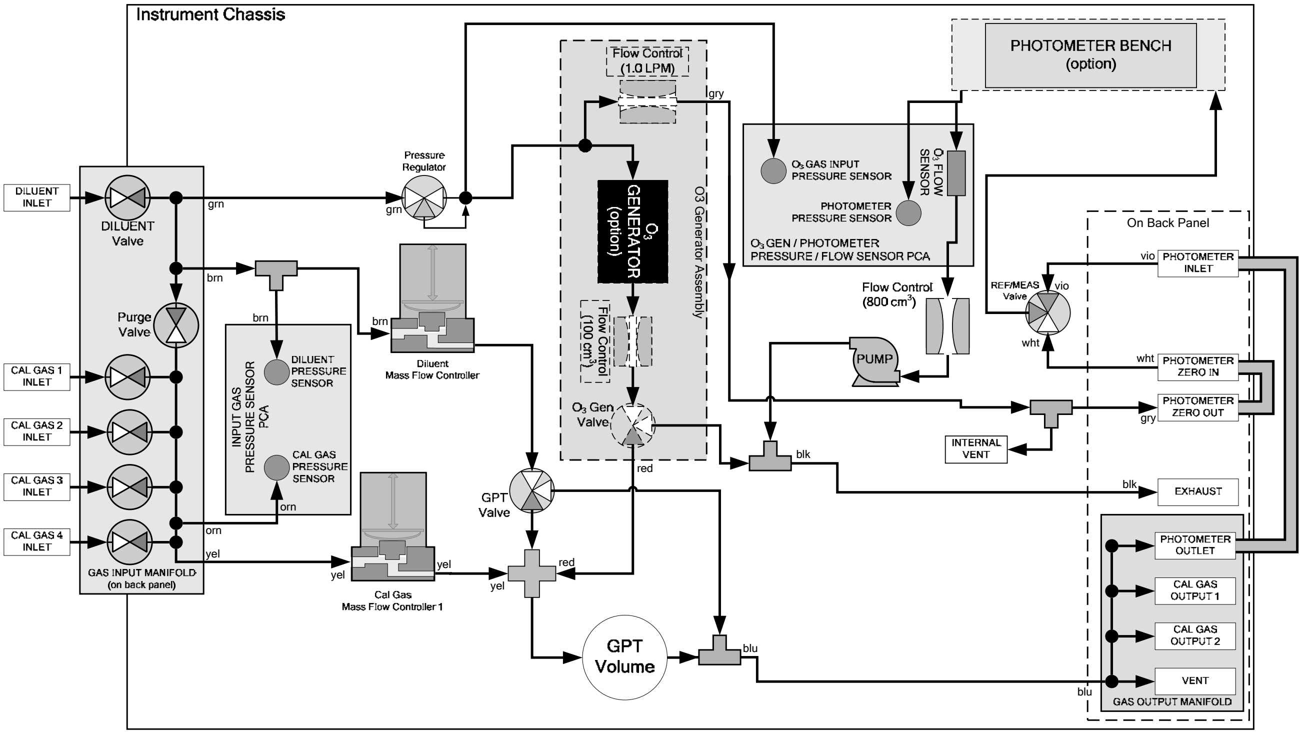


Figure 5-2: Internal Pneumatics for T700 Calibrator with Optional O_3 Generator and Photometer

Table 5-2: Operating Mode Valve States for T700 Calibrator with Optional O_3 Generator and Photometer

GAS TYPE	VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	X	X	Reference Phase	ON[3]	ON[3]	ON	OFF
Generate O_3	X	X	X	X	X	O	X	O	Switching	OFF	OFF	OFF	ON[4]
GPT	O[2]	O[2]	O[2]	O[2]	X	O	O	O	Reference Phase	ON[3]	ON[3]	ON	OFF
GPTPS	X	X	X	X	X	O	O	O	Switching	OFF	OFF	ON	ON[4]
PURGE	X	X	X	X	O	O	O	O	Reference Phase	ON[3]	ON[3]	ON	OFF
STANDBY	X	X	X	X	X	O	X	X	Reference Phase	OFF	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 instrument with multiple MFC's the CPU chooses which MFC to use depending on the target gas flow requested.
[4] When generating O_3 or in GPT Pre-Set mode, the photometer pump is the primary creator of gas flow through the T700. Flow rates are controlled by critical flow orifice(s) located in the gas stream

5.2. GAS FLOW OPTIONS

5.2.1. FLOW RATE OPTIONS (OPT 07A, OPT 7B, OPT 08A & OPT 08B)

The standard T700 Dynamic Dilution Calibrator is equipped with one calibration gas mass flow controller and one diluent gas mass flow controller. Table 5-3 shows the flow rates for the standard T700, as well as various flow rate options.

Table 5-3: T700 Gas Flow Rate Options

Option	Affected Mass Flow Controller	Flow rates	NOTES:
STANDARD	Cal/Source Gas MFC	0 – 100 cm^3/min	
	Diluent Gas MFC	0 – 10 LPM	
OPT – 07A	Cal/Source Gas MFC	0 – 50 cm^3/min	Replaces 0 – 100 cm^3/min Cal Gas MFC
OPT – 07B	Cal/Source Gas MFC	0 – 200 cm^3/min	Replaces 0 – 100 cm^3/min Cal Gas MFC
OPT – 08A	Diluent Gas MFC	0 – 5 LPM	Replaces 0 – 10 LPM Diluent Gas MFC
OPT – 08B	Diluent Gas MFC	0 – 20 LPM	Replaces 0 – 10 LPM Diluent Gas MFC

5.2.2. MULTIPLE CALIBRATION SOURCE GAS MFC

This option adds an additional mass flow controller on the calibration gas stream. When this option is installed the T700 has both calibration gas MFC's on the same gas stream, installed in parallel (see Figure 5-3 and Figure 5-4). 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 MFC's configured for 0-1 LPM and 0-5 LPM:

  Calibration gas flow rates:
  5.001 to 6.000 LPM; both MFC's active
  1.001 LPM – 5.000 LPM; High MFC active;
  10 cm^3/min – 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 MFC's. 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 MFC's.

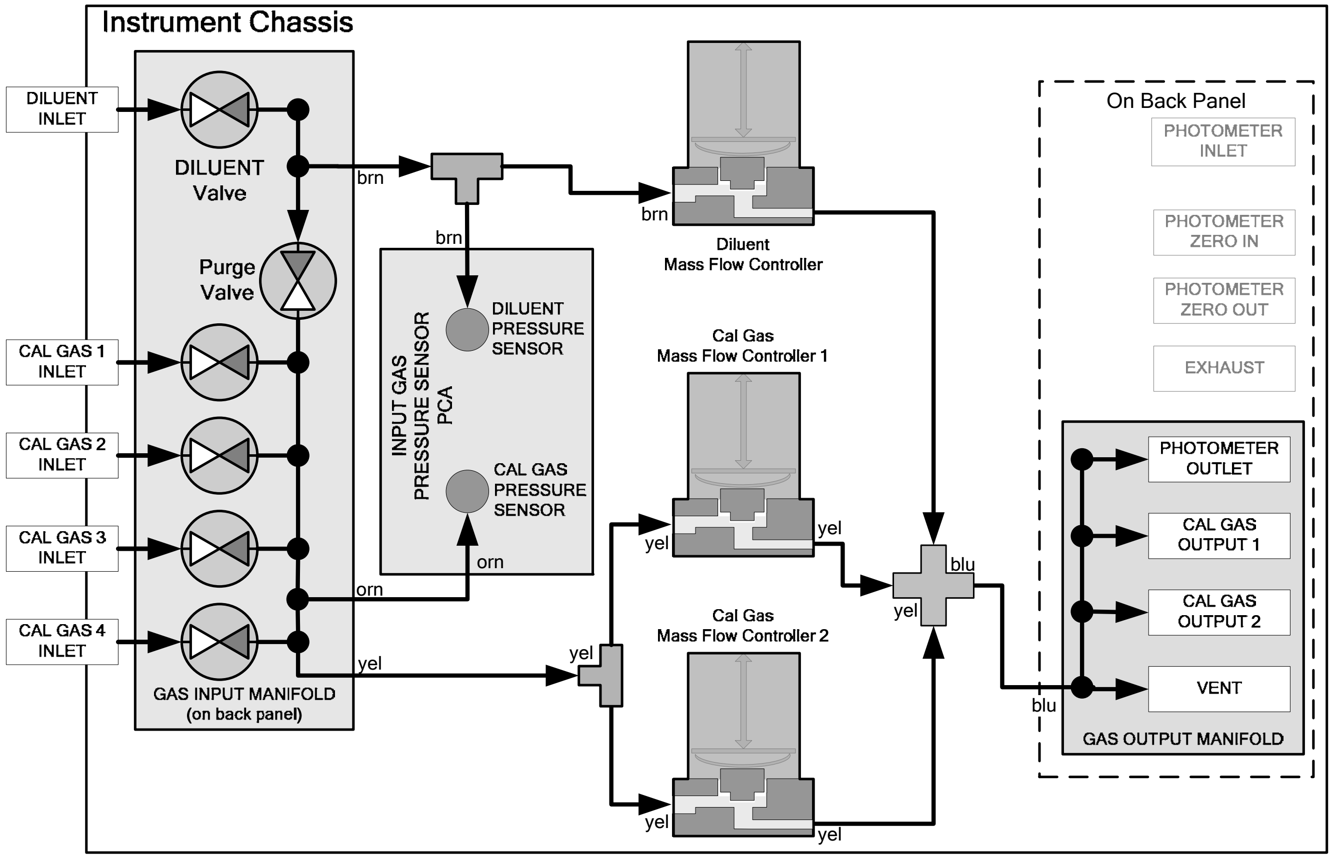


Figure 5-3: Basic T700 with Multiple Calibration Gas MFC's

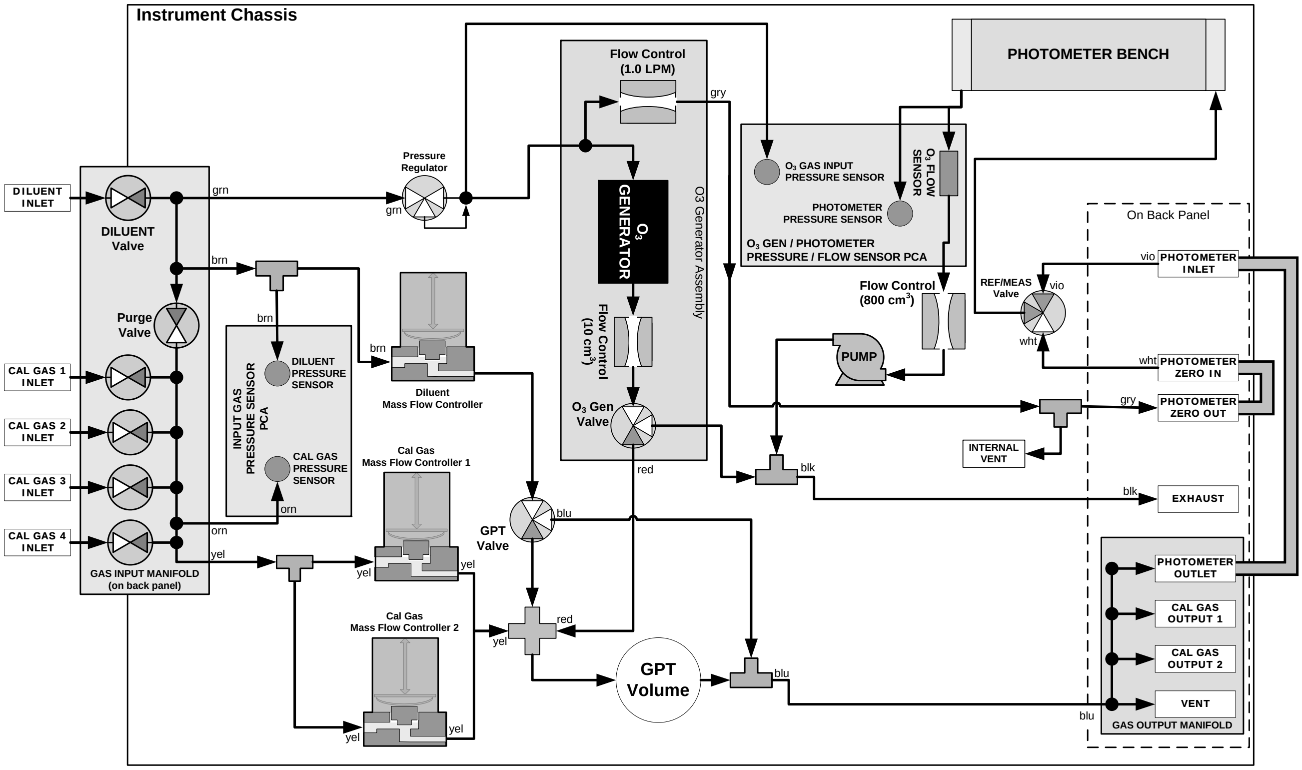


Figure 5-4: T700 with Multiple Calibration Gas MFC's and O_3 Options OPT 01A and OPT 02A Installed

5.3. RACK MOUNT KITS (OPT 20A, OPT 20B & OPT 21)

There are several options for mounting the calibrator in standard 19" racks. The slides are three-part extensions, one mounts to the rack, one mounts to the calibrator chassis and the middle part remains on the rack slide when the calibrator is taken out. The calibrator locks into place when fully extended and cannot be pulled out without pushing two buttons, one on each side.

The rack mount brackets for the calibrator require that you have a support structure in your rack to support the weight of the calibrator. The brackets cannot carry the full weight of a calibrator and are meant only to fix the calibrator to the front of a rack, preventing it from sliding out of the rack accidentally.

OPTION NUMBER	DESCRIPTION
OPT 20A	Rack mount brackets with 26 in. chassis slides, STD.
OPT 20B	Rack mount brackets with 24 in. chassis slides.
OPT 21	Rack mount brackets only

5.4. CARRYING STRAP HANDLE (OPT 29)

The chassis of the T700 calibrator allows to attach a strap handle for carrying the instrument. The handle is located on the right side and pulls out to accommodate a hand for transport. When pushed in, the handle is nearly flush with the chassis, only protruding out about 9 mm (3/8").

Installing the strap handle prevents the use of the rack mount slides, although the rack mount brackets, Option 21, can still be used.

CAUTION

A FULLY LOADED T700 WITH BOTH THE O_3 GENERATOR AND PHOTOMETER OPTIONS INSTALLED WEIGHS ABOUT 17 KG (40 POUNDS).

TO AVOID PERSONAL INJURY WE RECOMMEND TWO PERSONS LIFT AND CARRY THE CALIBRATOR.

ENSURE TO DISCONNECT ALL CABLES AND TUBING FROM THE CALIBRATOR BEFORE CARRYING IT.

5.5. SPARE PARTS KITS

5.5.1. T700 EXPENDABLES KIT (OPT 46A)

This kit includes a recommended set of expendables and spare parts (for 1 unit) for one year of operation of the T700. See Appendix B for a detailed listing of the contents.

5.5.2. T700 SPARE PARTS KIT (OPT 46B & OPT 46C)

This kit includes a recommended set of spare parts for one year of operation of T700's that have the optional O_3 generator and photometers installed. See Appendix B for a detailed listing of the contents.

OPTION NUMBER	DESCRIPTION
OPT 46B	Photometer Spares Kit for 1 unit.
OPT 46C	Photometer with IZS Spares Kit for 1 unit.

5.6. COMMUNICATION OPTIONS

5.6.1. SERIAL COMMUNICATIONS CABLES (OPT 60A, 60B, 60C, AND 60D)

For remote serial, network and Internet communication with the analyzer, the following communication cables are available:

Option	Type	Description
60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with a DB-25 serial connectors.
60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.
60C	Ethernet	Patch cable, 2 meters long.
60D	USB	Cable for connection between rear panel USB port and laptop computer.

5.6.2. RS-232 MULTI-DROP (OPT 62)

The multi-drop option is used with any of the RS-232 serial ports to enable communications of up to eight calibrators with the host computer over a chain of RS-232 cables via both rear panel DB9-connector COM ports. It is subject to the distance limitations of the RS-232 standard.

The option consists of a small printed circuit assembly, which is seated on the calibrator's CPU card, above the Disk-on Module, and uses both DB9 connectors on the instrument's back panel. One Option 62 is required for each calibrator along with one 6' straight-through, DB9 male → DB9 Female cable (P/N WR0000101).

5.7. ADDITIONAL MANUAL (OPT 70A & OPT 70B)

Additional copies of the printed user's manual can be purchased from the factory as Option 70A. Please specify the serial number of your calibrator so that we can match the manual version.

This operator's manual is also available on CD as option 70B. The electronic document is stored in Adobe Systems Inc. *Portable Document Format* (PDF) and is viewable with Adobe Acrobat Reader® software, which can be downloaded for free at http://www.adobe.com/.

The electronic version of this manual can also be downloaded for free at http://www.teledyne-api.com/manuals/. Note that the online version is optimized for fast downloading and may not print with the same quality as the manual on CD.

5.8. EXTERNAL VALVE DRIVER (OPT 48A & OPT 48B)

Either one of two external valve driver assemblies (12V or 24V) is available that can drive up to eight, 8-watt valves based on the condition of the status block bits described below The option consists of a custom Printed Circuit Assembly (PCA) that mounts to the back of the T700 and a universal AC-to-DC power supply.

Figure 5-5: T700 Rear Panel Valve Driver Installed

OPTION	DESCRIPTION
OPT 48A	External Valve Driver Capability – 12V
OPT 48B	External Valve Driver Capability – 24 V

Depending upon the capacity of the external supply either four (standard) or eight valves can be simultaneously energized.

The PCA is constructed such that it plugs through the rear panel into the Control Output connector, J1008, on the T700's motherboard.

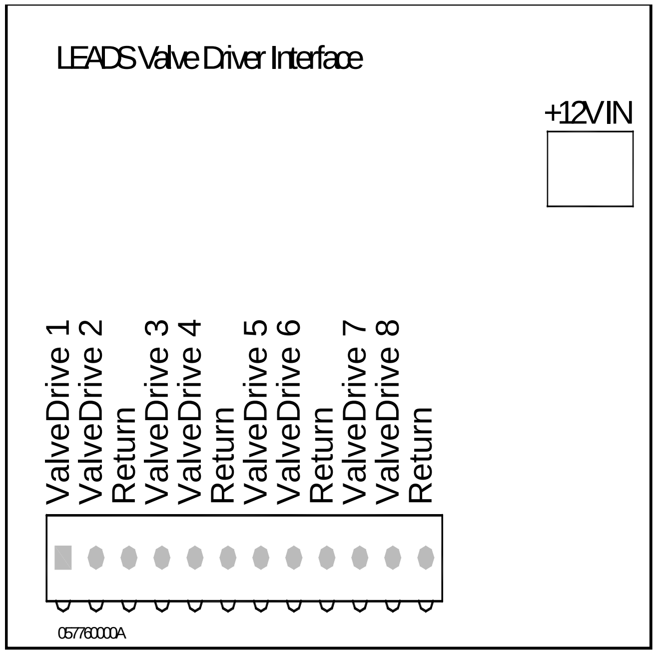


Figure 5-6: Valve Driver PCA Layout

When one of the Control Outputs is energized, the base of the associated PNP valve driver transistor (U1 through U8) is taken to ground and the emitter-collector junction becomes active.

Electronic connections should be made as follows:

- Valves should be connected between one of the Valve Drive outputs and one of the Return pins.
- The external power supply must be connected to the Valve Driver Interface using the +12V coaxial input connector on the top, right-hand side of the assembly.
- The external supply in turn must be connected to 85-264V, 47-63Hz mains.

The Valve Driver Outputs are mapped one-for-one to the Control Outputs 1 through 8 and can be manually actuated for troubleshooting using the Signal-I/O diagnostic function in the T700 software (see Section 11.4.11.5). However, the drive outputs are mapped in reverse to the status control bits such that Bit-0 (LSB) is valve drive 8 and Bit-7 is valve drive 1.

5.9. NIST TRACEABLE, PRIMARY STANDARD CERTIFICATION (OPT 95A, OPT 95B & OPT 95C)

The Model T700 calibrator can be used as a Primary Ozone Standard if purchased with the O_3 generator (OPT 01A) and photometer (OPT 02A) options. For this application the performance of the T700 Dynamic Dilution Calibrator calibrated to Standard Reference Photometer (SRP).

Calibrators ordered with this option are verified and validated in accordance with the procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D (40 CFR Part 50).

OPTION NUMBER	DESCRIPTION
OPT 95A	Factory Calibration
OPT 95B	Calibration as a primary standard
OPT 95C	Calibration to NIST-SRP

5.10. PERMEATION TUBE OVEN OPTION (OPT 05)

The permeation tube gas generator (see Figure 5-7) is an alternative method for producing known concentrations of stable gas such as SO_2, NO_2, etc. The generator consists of a temperature regulated permeation tube oven, a flow restrictor, an optional output desorber, and a user-supplied permeation tube. The optional desorber can improve the response time of the calibrator especially when operating with NO_2 tubes (when operating with sulfur based gases it **MUST** be removed).

The permeation tube consists of a small container of a liquefied gas, with a small window of PTFE through which the gas slowly permeates at a rate in the nanogram/min range. If the tube is kept at constant temperature, usually about 50°C, the device will provide a stable source of gas for a year or more. A pneumatic diagram of the T700 with this option is shown in Figure 5-8, including the generator.

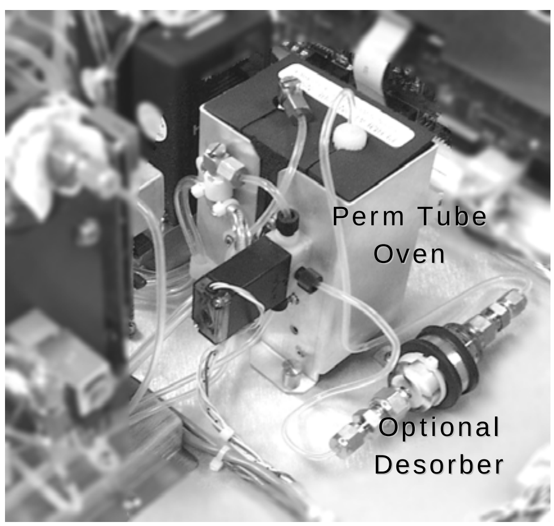


Figure 5-7: Permeation Tube Gas Generator Option

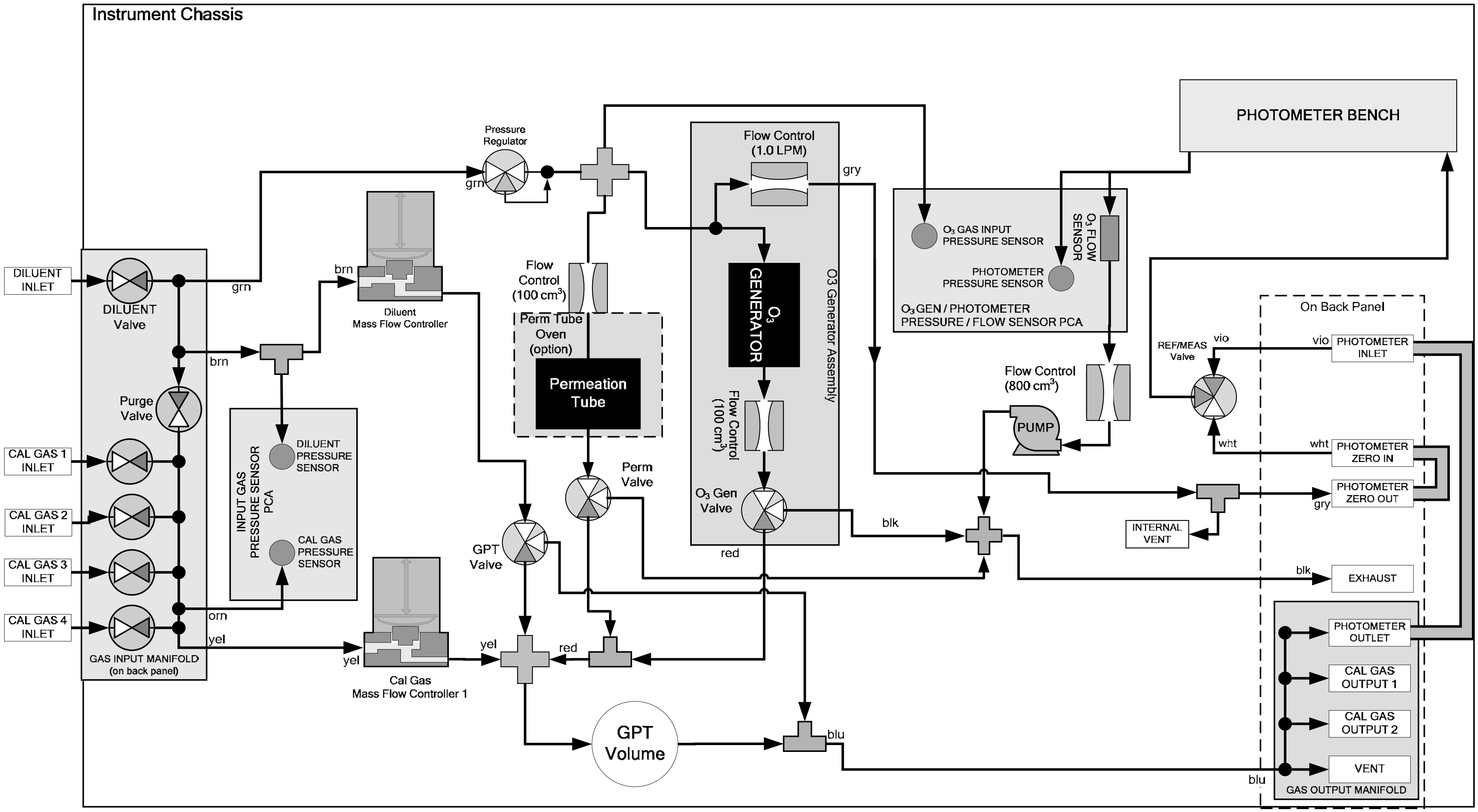


Figure 5-8: Pneumatic Diagram of T700 with Permeation Generator

Once installed and stabilized, generating a calibration gas from the T700 with a permeation generator is the same as if the gas was being produced using a gas cylinder as the source, with the following exceptions and note:

- If you need a particular flow and don't require a specific concentration then use MANUAL mode. When generating in MANUAL mode the output concentration is set by adjusting the DILUENT flow. The target and actual concentrations are displayed as test values.

- If you need a particular concentration but don't require a specific flow then use AUTO mode. When generating in AUTO mode the output concentration is set by entering the desired concentration. The TOTAL flow entry has no effect; the calibrator's output flow depends on the target concentration. Again the target and actual concentrations as well as the target and actual flows will be indicated as test parameters.

- Please note that the name for the permeation tube gas MUST be different than any gas supplied to the calibrator from a bottle. For example if there is a H_2S permeation tube installed and a bottle of H_2S gas connected to the calibrator, one should be named H_2S, while the second should be named something like H_2S_2.

The generator is shipped **WITHOUT** a permeation tube installed. The tube **MUST** be **removed** during shipping or anytime that there is no dilutant gas connected to the calibrator since there must be a continuous purge flow across the tube. Permeation tubes require 48 hours at 50°C to reach a stable output. We recommend waiting this long before any calibration checks, adjustments, or conclusions are reached about the permeation tube. Once the T700 has stabilized, the response to the permeation tube is not expected to change more than ± 5% if the zero air is provided for Teledyne API's M701 or other dry zero air source.

Teledyne API recommends that you purchase replacement permeation tubes from:

VICI METRONICS
2991 Corvin Drive
Santa Clara, CA 95051 USA
Phone 408-737-0550 Fax 408-737-0346

5.10.1. PERMEATION TUBE SETUP FOR THE T700

1. Press SETUP and GAS

```
SETUP X.X      PRIMARY SETUP MENU
 GAS   SEQ  CFG  CLK  PASS  MORE        EXIT
```

2. Press PERM

```
SETUP X.X      SOURCE GAS CONFIG
 CYL  PERM  USER                        EXIT
```

3. Enter the elution rate for the permeation tube and select the type of gas by pressing the gas button to scroll through the gas list until the desired gas is shown.

NOTE

The name of the gas produced by the permeation tube generator MUST be different from the name of any bottle connected to the calibrator.

SETUP X.X	PERM TUBE 1:10.0 NGM NO2						
0	1	0	.0	NGM	NO2	ENTR	EXIT

4. Then enter the gas flow through the permeation tube. This should be done with the flow standard connected at the outlet of the perm tube oven.

SETUP X.X	PERM TUBE 1:0.105 LPM				
0	.1	0	5	ENTR	EXIT

5.10.2. PERMEATION TUBE CALCULATION

The permeation tube concentration is determined by the permeation tube's specific output or elution rate (which is normally stated in ng/min), the permeation tube temperature (°C) and the air flow across it (slpm). The elution rate of the tube is normally stated at an operating temperature of 50°C and is usually printed on the tube's shipping container. By design, there is nominally 100 ccm of air flow across the tube and the tube is maintained at 50°C. The output of the calibrator is the product of the elution rate with the total of the 100 sccm through the generator and the flow of dilutent gas.

The temperature is set at 50.0°C. Check SETUP-MORE-VARS and scroll to the IZS-TEMP variable to verify that the temperature is properly set. It should be set to 50°C with over-and-under temperature warnings set at 49°C and 51°C. There is a 105 cm^3/min flow across the permeation tube at all times to prevent build-up of the gas in the tubing.

This permeation tube source gas is diluted with zero air to generate desired concentration of the specific gas. The calibrator's output concentration (gas concentration) can be calculated using the following equation:

$$C = \frac{P \times Km}{F}$$

Where, P = permeation rate, ng/min @ 50°C.

Km = $\frac{24.46}{MW}$, where 24.46 is the molar volume in liters @ 25°C

and MW is the molecular weight.
760mmHg . Km for SO_2 = 0.382, NO_2 = 0.532, H_2S = 0.719, and NH_3 = 1.436.

F = total flow rate (sum of 100 cm^3/min and diluent flow), cm^3/min.

C = concentration, ppm.

Thus, $$C = \frac{P}{F} \times \frac{24.46}{MW}\left(\frac{323}{298}\right)$$

Where, Temperature at 50°C = 323

Temperature at 25°C = 298

5.11. EXTENDED WARRANTY (OPT 92B & OPT 92C)

Options available to extend the warranty (see *Warranty* at front of this manual) by 1, 2, 3, or 4 years, must be specified upon ordering the analyzer.

Option Number	Description
92A	1-year extended warranty
92B	2- year extended warranty
92C	3- year extended warranty
92D	4- year extended warranty

5.12. DUAL GAS OUTPUT (NO_Y – SPECIAL) (OPT 73)

The standard output manifold has been removed and replaced with 2 output fittings, labeled “Output A” and “Output B.” Output A is the primary calibration gas output, all calibration functions can be performed on this output. Output B is a secondary output, commonly used for NOy probe calibrations. This output cannot be used for ozone generation using the photometer feedback. It can be used for standard dilution calibrations as well as GPT using ozone.

When the dual gas output option is enabled, the output must be selected when generating gas. See example as follows:

1. In STANDBY mode press SETUP and then press MORE to enter the Secondary Setup Menu.

```
SETUP          PRIMARY SETUP MENU
 GAS   SEQ  CFG  CLK  PASS  MORE        EXIT
```

2. Press DIAG.

```
SETUP          SECONDARY SETUP MENU
COMM  FLOW VARS  DIAG                      EXIT
```

WARNING

THERE ARE MORE VARS AVAILABLE WHEN USING THE 929 PASSWORD. USE CAUTION WHEN PRESSING ANY BUTTONS WHILE IN THIS SETUP. ANY CHANGES MADE MAY ALTER THE PERFORMANCE OF THE INSTRUMENT OR CAUSE THE INSTRUMENT TO NOT FUNCTION PROPERLY. NOTE THAT IF THERE IS AN ACCIDENTAL CHANGE TO A SETUP, PRESS "EXIT" TO DISCARD THE CHANGES MADE.

3. Enter the password 929 and press ENTR.

```
SETUP       ENTER PASSWORD:929
9     2     9                    ENTR     EXIT
```

4. Press NEXT until you get to the Factory Options submenu and press ENTR.

```
DIAG          FACTORY OPTIONS
 PREV   NEXT                   ENTR          EXIT
```

5. Press NEXT until you reach the Dual Gas Output submenu.

```
DIAG OPT      DUAL GAS OUTPUT=ON
 PREV   NEXT   ON                    ENTR   EXIT
```

If the display shows that the Dual Gas Output is OFF, an "OFF" button should display; press it to change the state of Dual Gas Output to ON.

6. Press ENTR to return to the FACTORY OPTIONS; then press EXIT until you return to Standby mode.

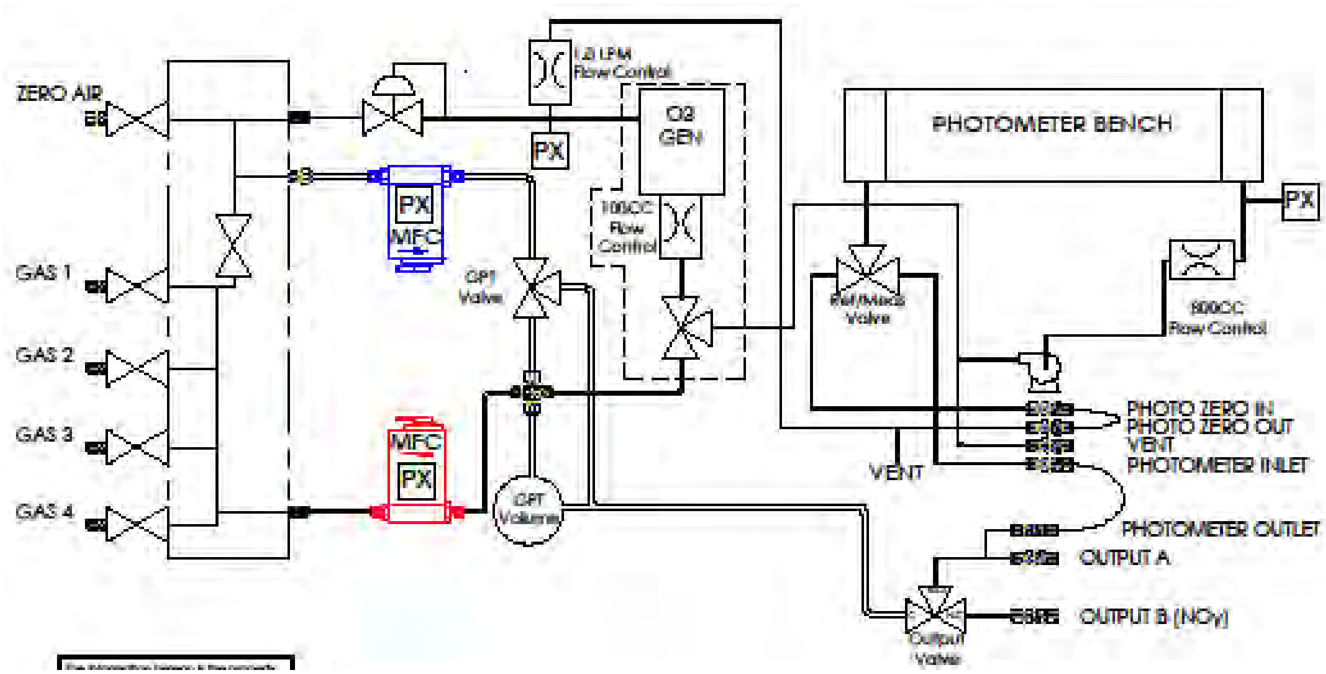


Figure 5-9: Internal Pneumatics for T700 Calibrator with Optional Dual Gas Output (NO_y – Special)

PART II
–
OPERATING INSTRUCTIONS

6. BASIC OPERATION

The T700 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 front panel touch screen control.

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 front panel touch screen is used to operate the T700 Dynamic Dilution 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.

6.1. TEST FUNCTIONS

A variety of **TEST** functions are available for viewing at the front panel whenever the calibrator is at the **MAIN MENU**. These functions provide information about the present operating status of the calibrator and are useful during troubleshooting (see Section 11). Table 6-1 lists the available **TEST** functions.

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

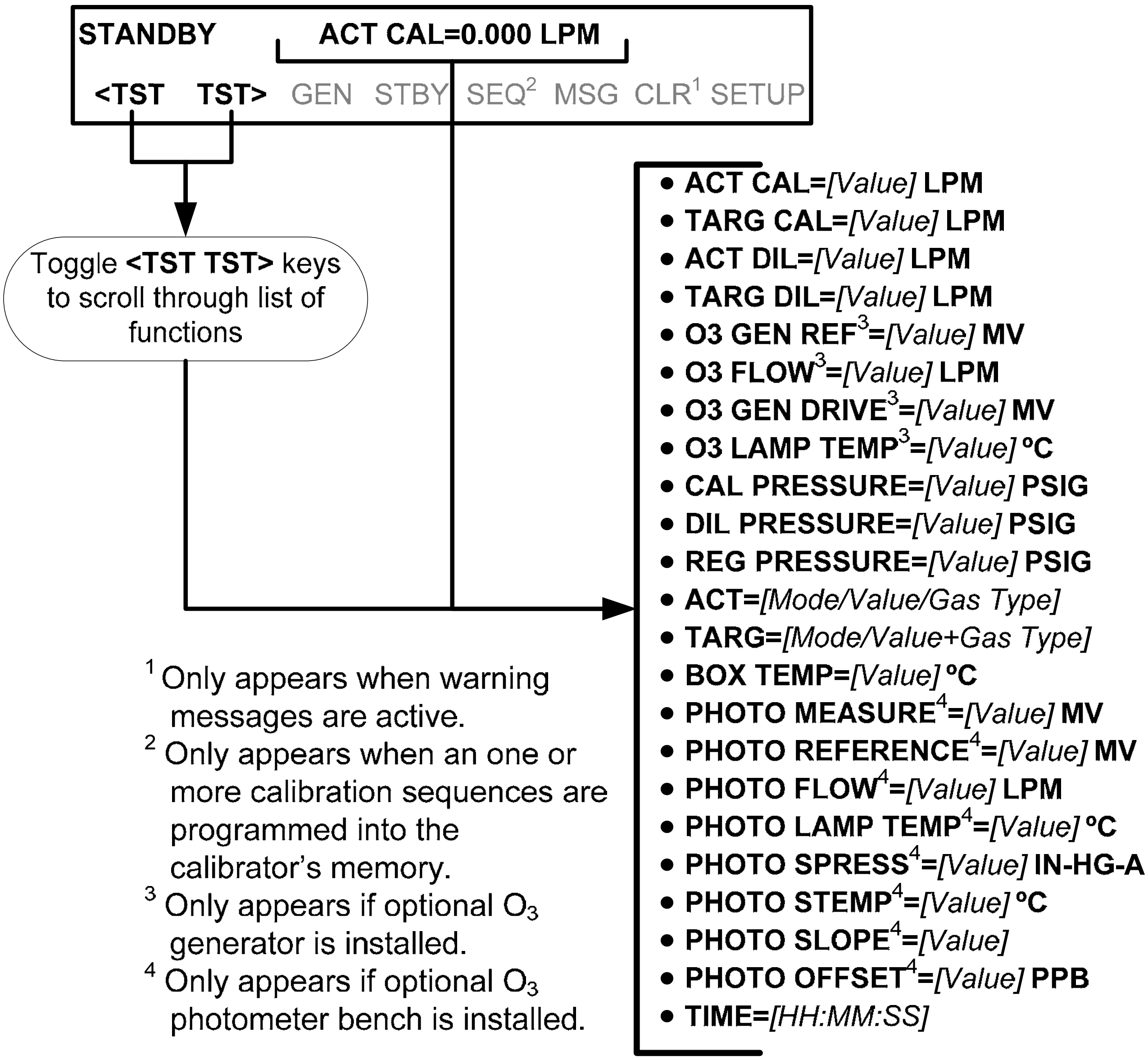


Figure 6-1: Viewing T700 Test Functions

Table 6-1: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
ACT CAL		LPM	The actual gas flow rate of source gas being output by the calibrator.
TARG CAL		LPM	Target source gas flow rate for which the calibrator output is set.
ACT DIL		LPM	The actual gas flow rate of diluent (zero) gas being output by the calibrator.
TARG DIL		LPM	Target diluent (zero) gas flow rate for which the calibrator output is set.
O3 GEN REF[1]		mV	The voltage being output by the O_3 generator reference detector.
O3 FLOW[1]		LPM	The gas flow rate for which the O_3 generator is set.
O3 GEN DRIVE[1]		mV	The drive voltage of the O_3 generator UV lamp.
O3 LAMP TEMP[1]		°C	O_3 generator UV lamp temperature.
CAL PRESSURE		PSIG	The gas pressure of the source gas being supplied to the calibrator.
DIL PRESSURE		PSIG	The gas pressure of the Diluent gas being supplied to the calibrator Diluent pressure.
REG PRESSURE[2]		PSIG	The gas pressure at the pressure regulator on the O_3 generator supply line.
ACT			Actual concentration, and in some modes the actual flow rate, of the source gas in the calibration mixture being generated is displayed.
TARG			The Target concentration, and in some modes the target flow rate, of the source gas in the calibration mixture being generated is displayed.
BOX TEMP		°C	Internal chassis temperature.
PHOTO MEASURE[2]		mV	The average UV Detector output during the SAMPLE PORTION of the optional photometer's measurement cycle.
PHOTO REFERENCE[2]		mV	The average UV Detector output during the REFERENCE portion of the optional photometer's measurement cycle.
PHOTO FLOW[2]		LPM	The gas flow rate as measured by the flow sensor located between the optical bench and the internal pump.
PHOTO LAMP TEMP[2]		°C	The temperature of the UV lamp in the photometer bench.
PHOTO SPRESS[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.
PHOTO STEMP[2]		°C	The temperature of the gas inside the sample chamber of the photometer.
PHOTO SLOPE[2]		1.000	Photometer slope computed when the photometer was calibrated at the factory.
PHOTO OFFSET[2]		ppb	Photometer offset computed when the photometer was calibrated at the factory.
TEST		mV	Displays the analog signal level of the **TEST** analog output channel. Only appears when the **TEST** channel has been activated.
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.

6.2. OVERVIEW OF OPERATING MODES

The T700 calibrator software has a variety of operating modes. 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 front panel display), although **TEST** functions and **WARNING** messages are still updated and can be examined via the front panel display.

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 6-2: Front Panel Display

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

Besides **STANDBY** and **SETUP**, other modes the calibrator can be operated in are listed in Table 6-2:

Table 6-2: Calibrator Operating Modes

MODE	MEANING
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.
GENERATE	In this mode, the instrument is engaged in producing calibration gas mixtures.
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.
GPTPS[2]	Stands for Gas Phase Titration Preset. In this mode the T700 determines the precise performance characteristics of the O_3 generator at the target values for an upcoming GPT calibration.
MANUAL	In this mode, the instrument is engaged in producing calibration gas mixtures.
PURGE	The calibrator is using diluent (zero air) to purge its internal pneumatics of all source gas and previously created calibration mixtures.
SETUP[3]	**SETUP** mode is being used to configure the calibrator.
STANDBY	The calibrator and all of its subsystems are inactive.

[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.

[3] The revision of the Teledyne API software installed in this calibrator will be displayed following the word **SETUP**. E.g. "**SETUP G.4**"

6.3. STANDBY MODE

When the T700 Dynamic Dilution 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 which 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 MFC's are turned OFF. This prevents erroneous **MASS FLOW WARNING** messages from appearing.

NOTE

The T700 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 6-3 shows the status of the T700's various pneumatic components when the calibrator is in **STANDBY** mode.

Table 6-3: Status of Internal Pneumatics During STANDBY Mode

VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
CYL1	CYL2	CYL3	CYL4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R[1]	CAL1	CAL2[1]	DILUENT	
X	X	X	X	X	O	X	X	Reference Phase	OFF	OFF	OFF	OFF

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

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.

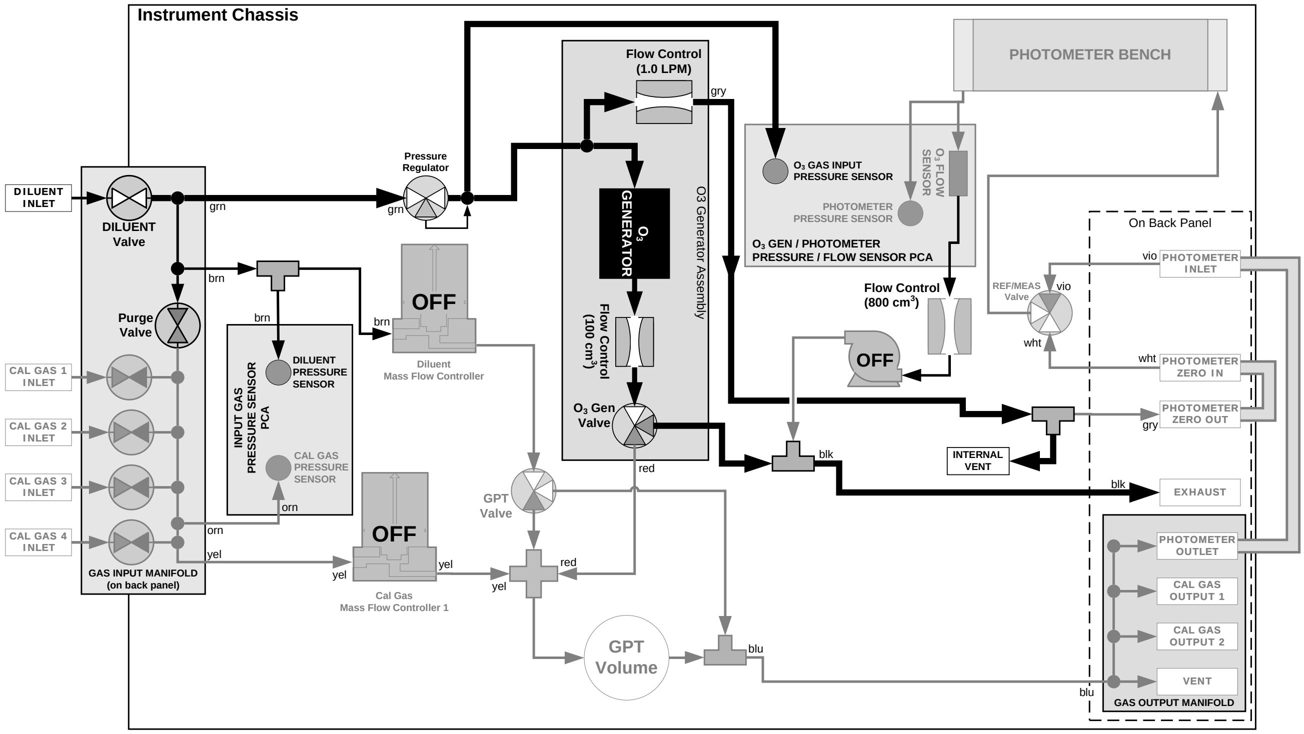


Figure 6-3: Gas Flow through T700 with O_3 Generator and Photometer Options during STANDBY

6.4. GENERATE MODE

6.4.1. GENERAL INFORMATION ABOUT THE GENERATE MODE

This 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 3.3.8). If the units has an optional O_3 generator installed, various concentrations of O_3 can be generated as well.

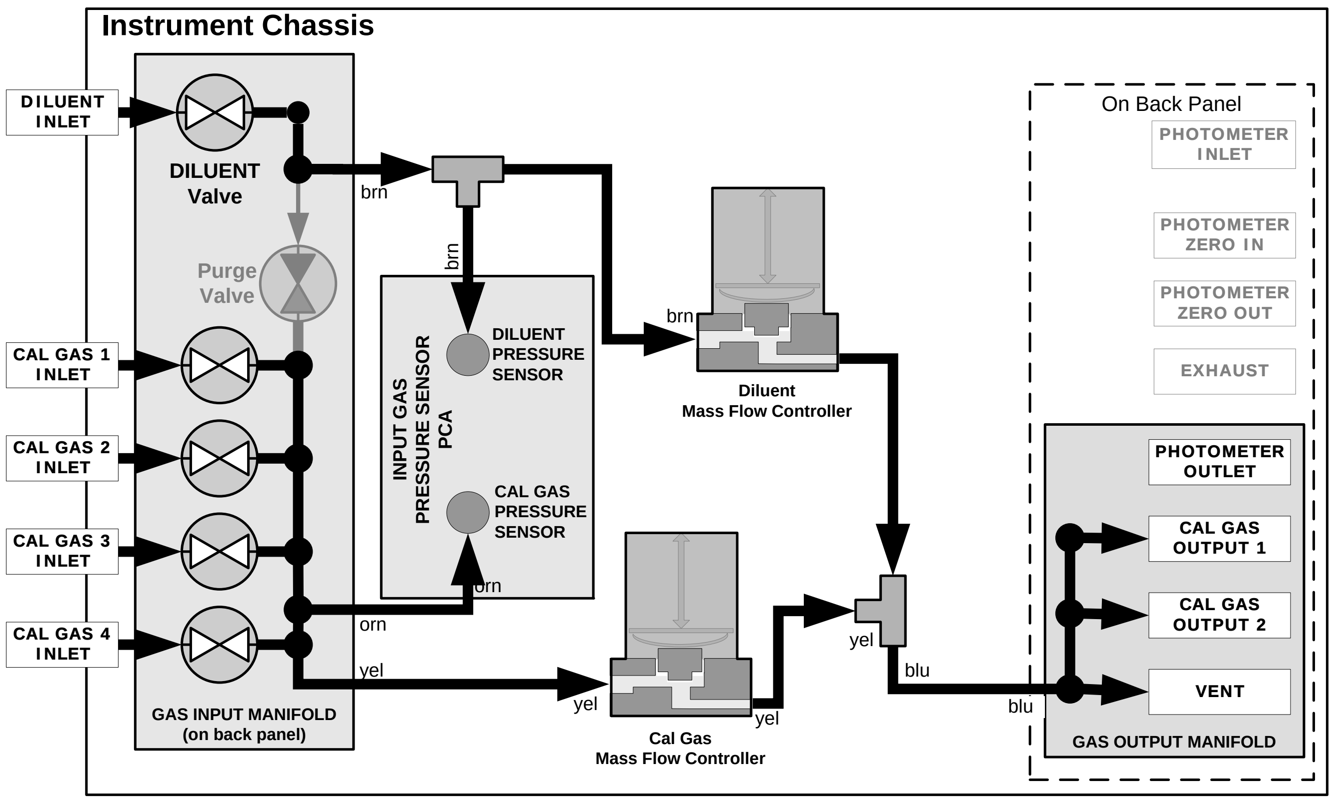


Figure 6-4: Gas Flow through Basic T700 in GENERATE Mode

Table 6-4 shows the status of the T700's various pneumatic components when the calibrator is in **GENERATE** mode:

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

GAS TYPE	VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
Generate Source Gas	O[2]	O[2]	O[2]	O[2]	X	O	X	X	Reference Phase	ON[3]	ON[3]	ON	OFF
Generate O_3	X	X	X	X	X	O	X	O	Switching	OFF	OFF	OFF	ON

[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 instrument with multiple MFC's the CPU chooses which MFC to use depending on the target gas flow requested.

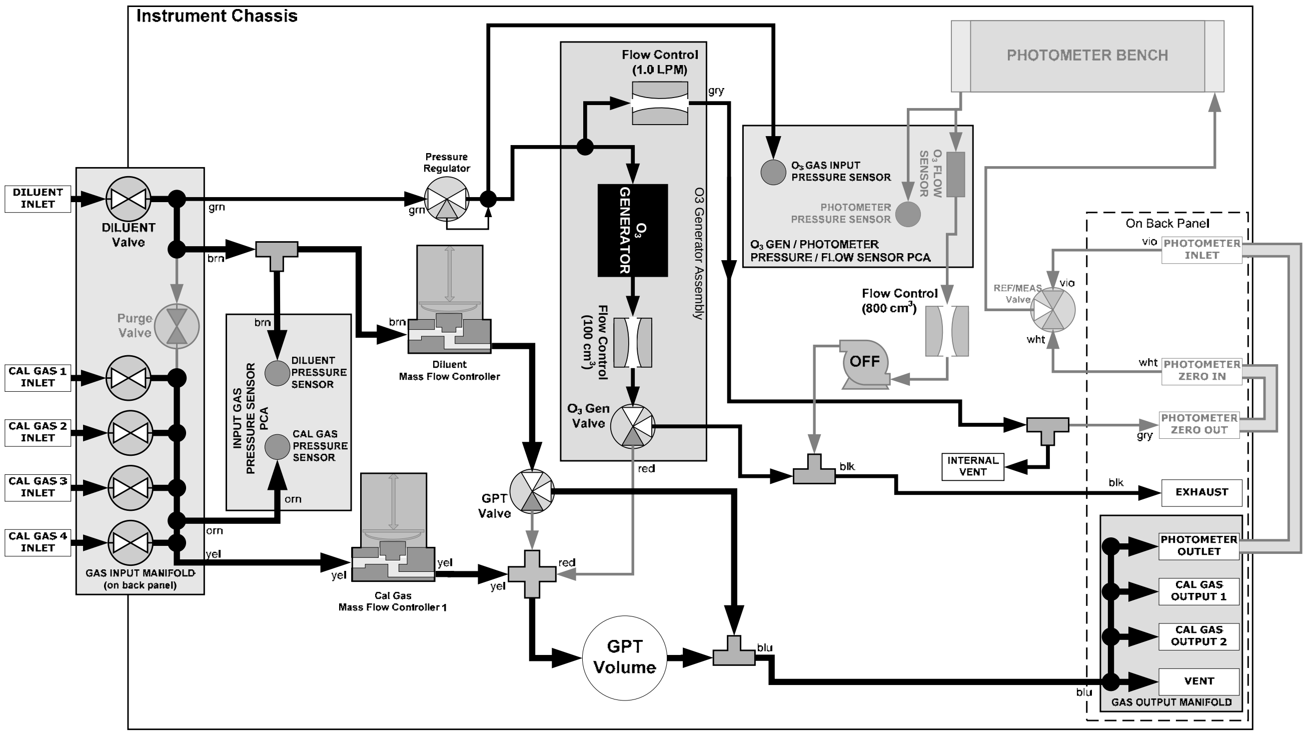


Figure 6-5: Gas Flow through T700 with O_3 Options when Generating Non-O_3 Source Gas

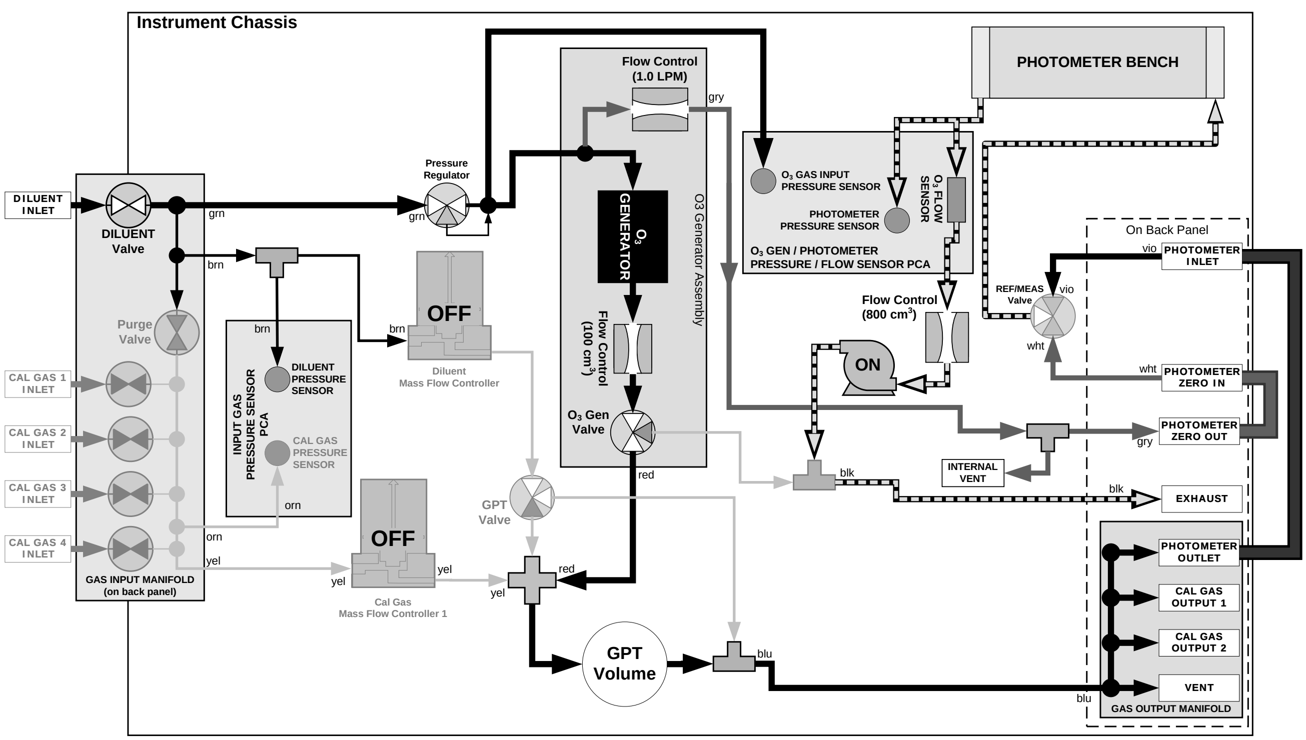


Figure 6-6: Gas Flow through T700 with O_3 Options when Generating O_3

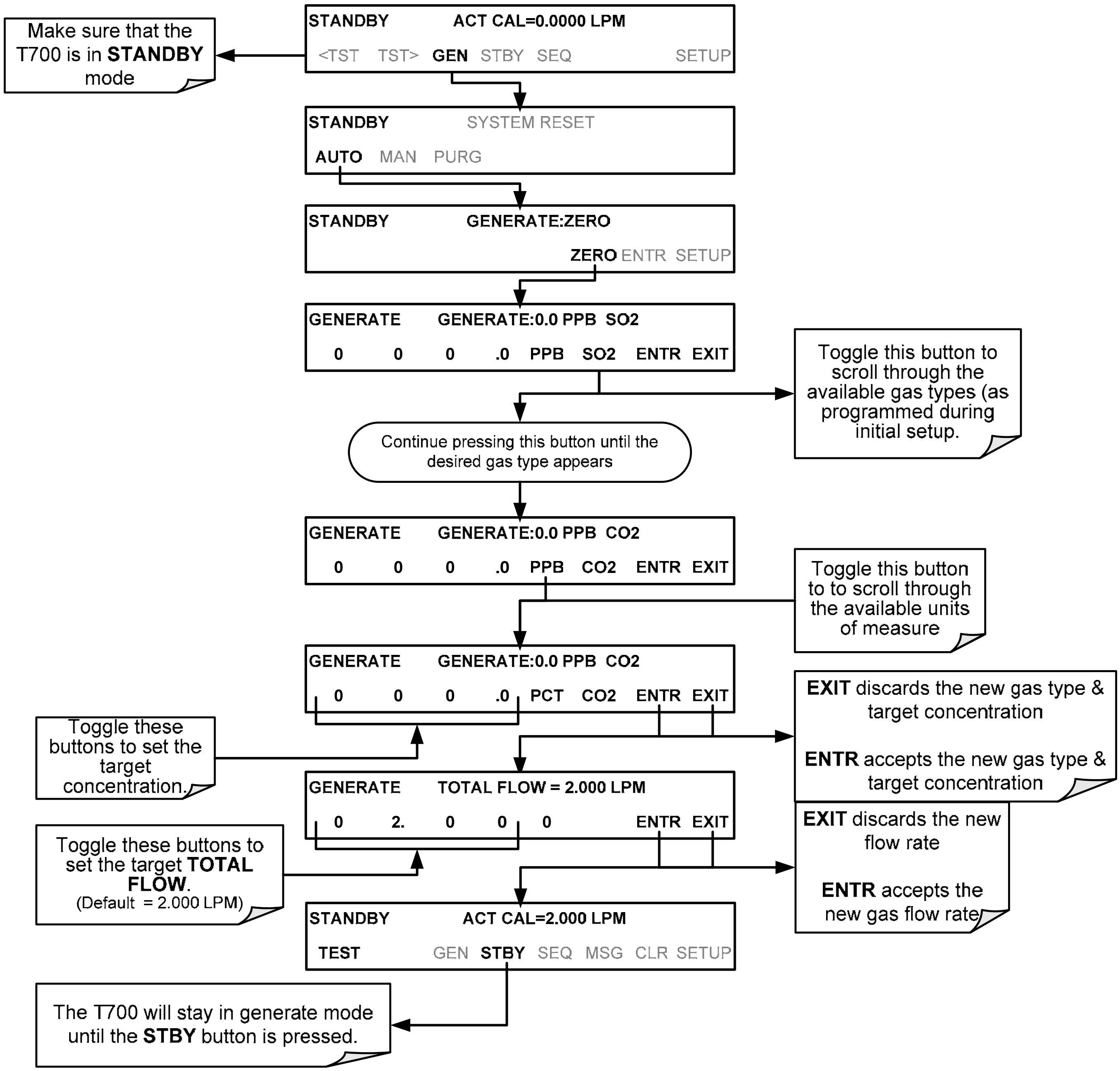
6.4.2. GENERATE → AUTO: Basic Generation of Calibration Mixtures

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 3.3.8);
- The target concentration, and;
- The **TOTAL FLOW** to be output by the T700.

Using this information, the T700 calibrator automatically calculates and sets the individual flow rates for the Diluent and chosen component gases to create the desired calibration mixture.

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


Make sure that the T700 is in STANDBY mode
STANDBY ACT CAL=0.0000 LPM
<TST TST> GEN STBY SEQ SETUP
STANDBY SYSTEM RESET
AUTO MAN PURG
STANDBY GENERATE:ZERO
ZERO ENTR SETUP
GENERATE GENERATE:0.0 PPB SO2
0 0 0 .0 PPB SO2 ENTR EXIT
Toggle this button to scroll through the available gas types (as programmed during initial setup.
Continue pressing this button until the desired gas type appears
GENERATE GENERATE:0.0 PPB CO2
0 0 0 .0 PPB CO2 ENTR EXIT
Toggle this button to to scroll through the available units of measure
GENERATE GENERATE:0.0 PPB CO2
0 0 0 .0 PCT CO2 ENTR EXIT
EXIT discards the new gas type & target concentration
ENTR accepts the new gas type & target concentration
Toggle these buttons to set the target concentration.
GENERATE TOTAL FLOW = 2.000 LPM
0 2. 0 0 0 ENTR EXIT
EXIT discards the new flow rate
ENTR accepts the new gas flow rate
Toggle these buttons to set the target TOTAL FLOW.
(Default = 2.000 LPM)
STANDBY ACT CAL=2.000 LPM
TEST GEN STBY SEQ MSG CLR SETUP
The T700 will stay in generate mode until the STBY button is pressed.

6.4.3. 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 T700 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 T700 will be supplying calibration gas.**
- **Example: If the T700 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

6.4.3.1. Determining the Source Gas Flow Rate

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

Equation 6-1

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

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

6.4.3.2. Determining the Diluent Gas Flow Rate

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

Equation 6-2

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

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

6.4.3.3. 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 T700's front panel. A typical value for O_{3flow} is 105 cm^3/min.

Equation 6-3

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

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.

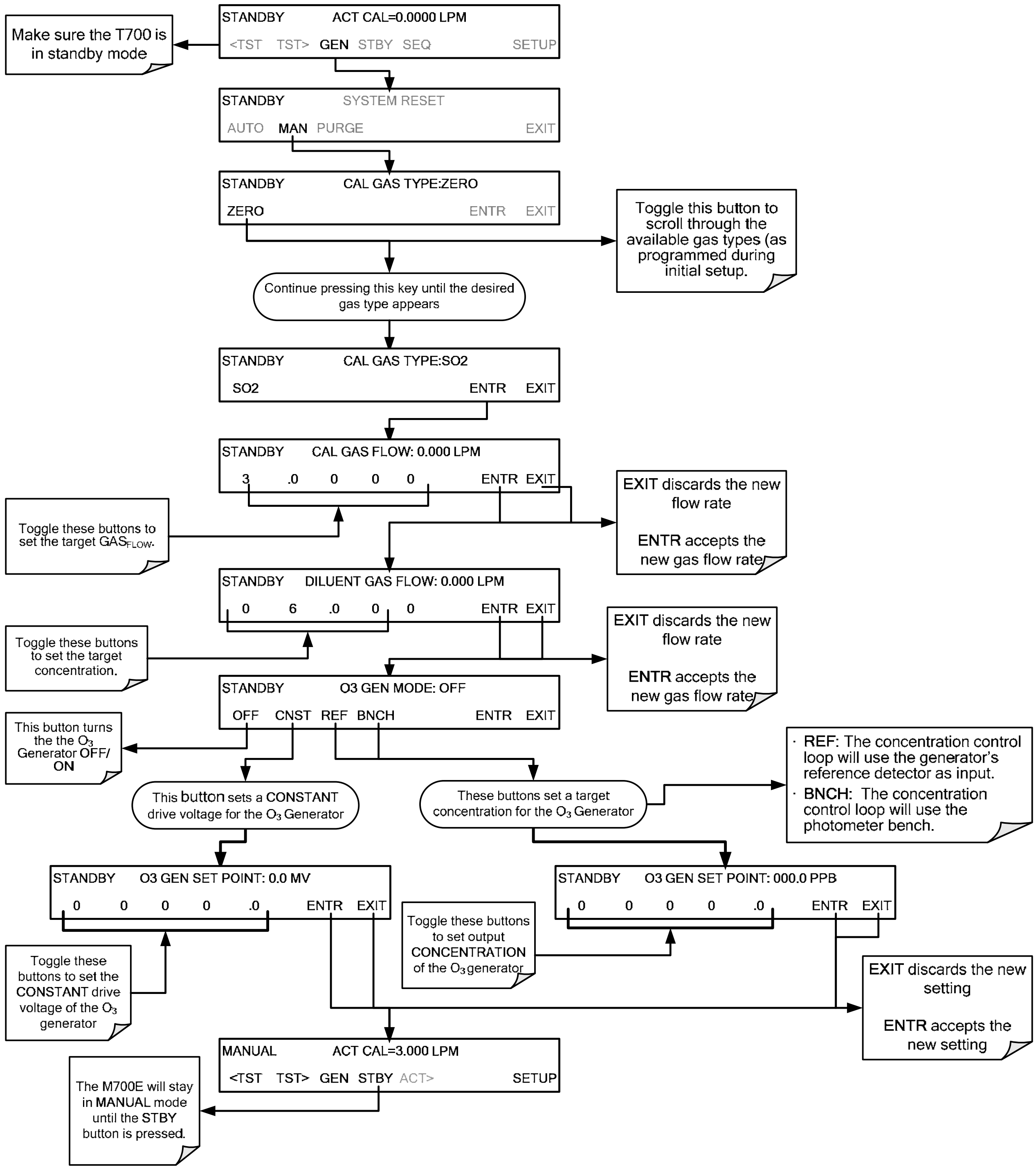
<u>FOR T700'S WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED.</u>

- **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 T700 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.**

6.4.3.4. 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 T700 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:



6.4.4. GENERATE → GPT: Performing a Gas Phase Titration Calibration

6.4.4.1. 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 6-4

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

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:

a) The amount of O_3 used in the mixture is known.

b) The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O_3 in the mixture.

c) The volume of the mixing chamber is known.

d) 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 T700 will be equal to (at a 1:1 ratio) to the amount of O_3 added.

Since the O_3 flow rate of the T700'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 T700 adjusts the NO flow rate and diluent (zero air) flow rate to create the appropriate NO_2 concentration at the output.

6.4.4.2. 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 is also kept constant three of the four conditions listed in Section 6.4.4.1 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.

6.4.4.3. 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 T700 will be supplying calibration gas.

EXAMPLE:

- If the T700 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

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.

<u>FOR T700'S WITH MULTIPLE CALIBRATIONS MASS FLOW CONTROLLERS INSTALLED.</u>

- **The full combined flow potential of both mass flow controllers is available to use 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 T700 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.**

Given this information, the T700 calibrator determines the NO gas flow by the formula:

Equation 6-5

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

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 6-6

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

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

6.4.4.4. T700 Calibrator GPT Operation

The following table and figures show the status of the T700's internal pneumatic components and internal gas flow when the instrument is in **GPT** generating modes.

Table 6-5: Status of Internal Pneumatics During GENERATE → GPT Mode

MODE	VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
GPT	O[2]	O[2]	O[2]	O[2]	X	O	O	O	Reference Phase	ON[3]	ON[3]	ON	OFF

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

[2] The valve associated with the cylinder containing NO source gas is open.

[3] In instrument with multiple MFC's the CPU chooses which MFC to use depending on the target gas flow requested.

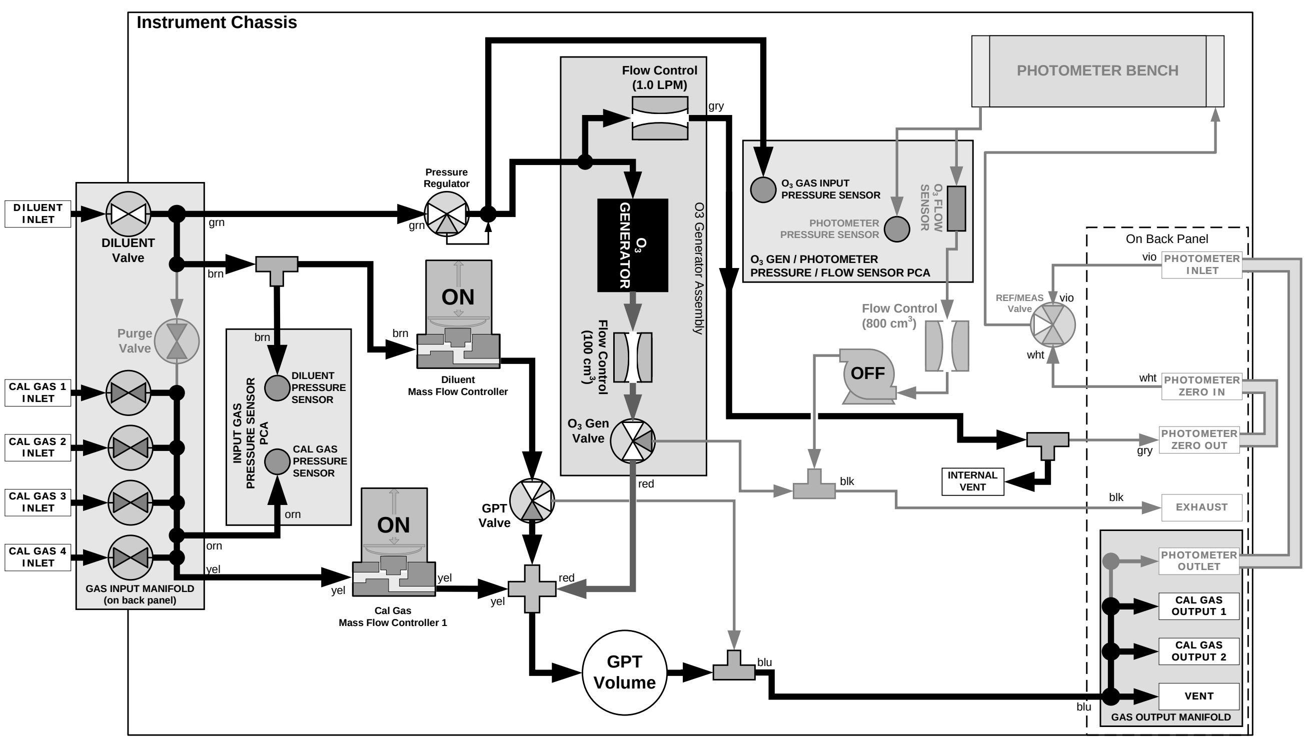


Figure 6-7: Gas Flow through T700 with O_3 Options when in GPT Mode

6.4.4.5. Initiating a GPT Calibration Gas Generation

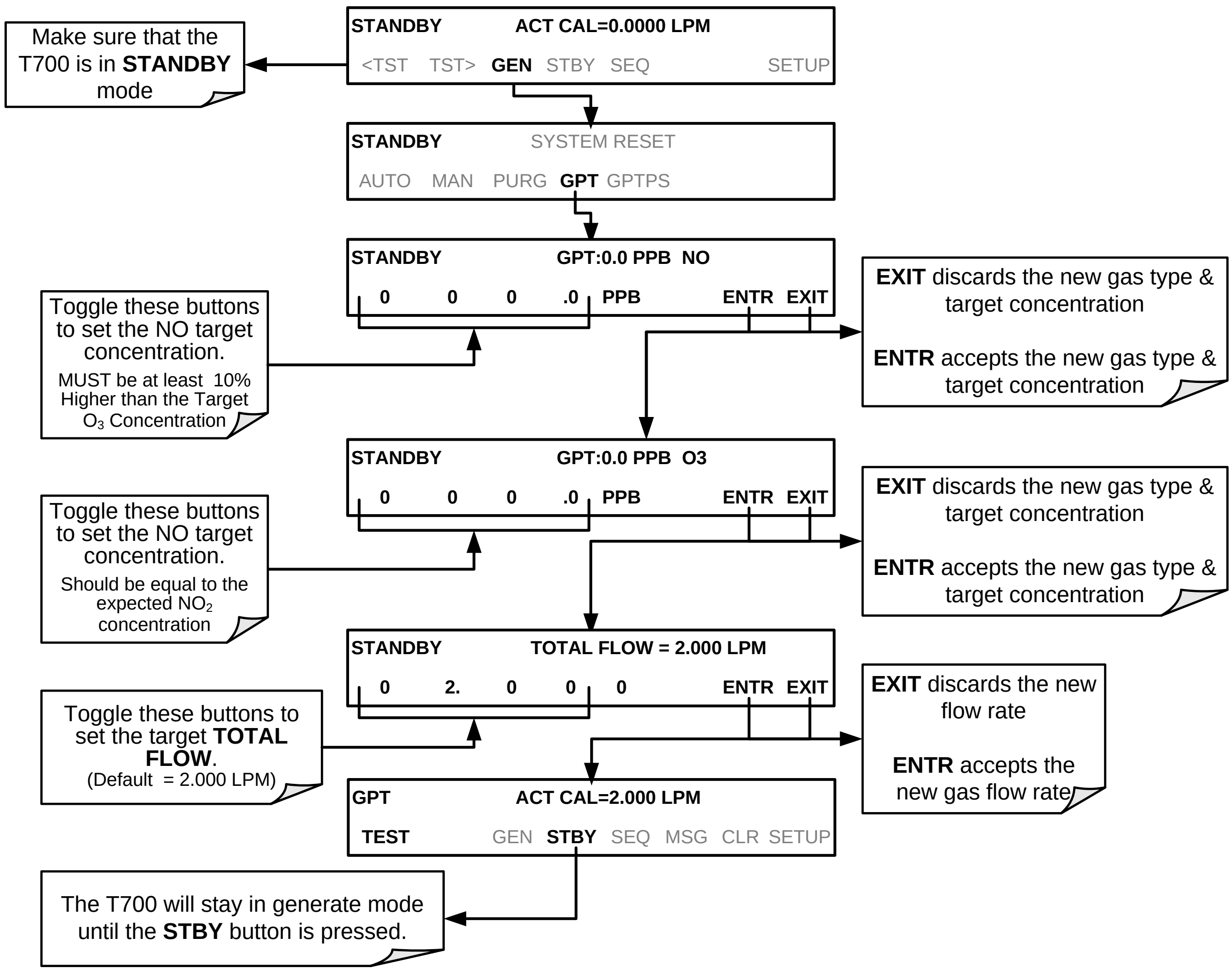
NOTE

It is highly recommended to perform a GPT Pre-Set 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:



6.4.5. GENERATE → GPTPS: Performing a Gas Phase Titration Pre-Set

The GPT Pre-Set feature simulates a **GPT** mixing operation in order to determine the exact output of the calibrators O_3 generator. As described in Section 6.4.4.1, all other things being equal, the concentration of the NO_2 being generated using 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 T700'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 T700 has a learning algorithm during the O_3 generation (see Section 6.4) or Gas Phase Titration Pre-Set Mode (GPTPS) (Sections 6.4.4.5 and 6.4.5). 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 Presets 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 adjust the flow rate of the diluent gas to substitutes an amount of diluent gas equal to the amount of NO gas that would normally be used.

6.4.5.1. T700 Calibrator GPTPS Operation

The following table and figures show the status of the T700's internal pneumatic components and internal gas flow when the instrument is in **GPTPS** generating modes.

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

MODE	VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
GPTPS	X	X	X	X	X	O	O	O	Switching	OFF	OFF	ON	ON

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

[2] The valve associated with the cylinder containing NO source gas is open.

[3] In instrument with multiple MFC's the CPU chooses which MFC to use depending on the target gas flow requested.

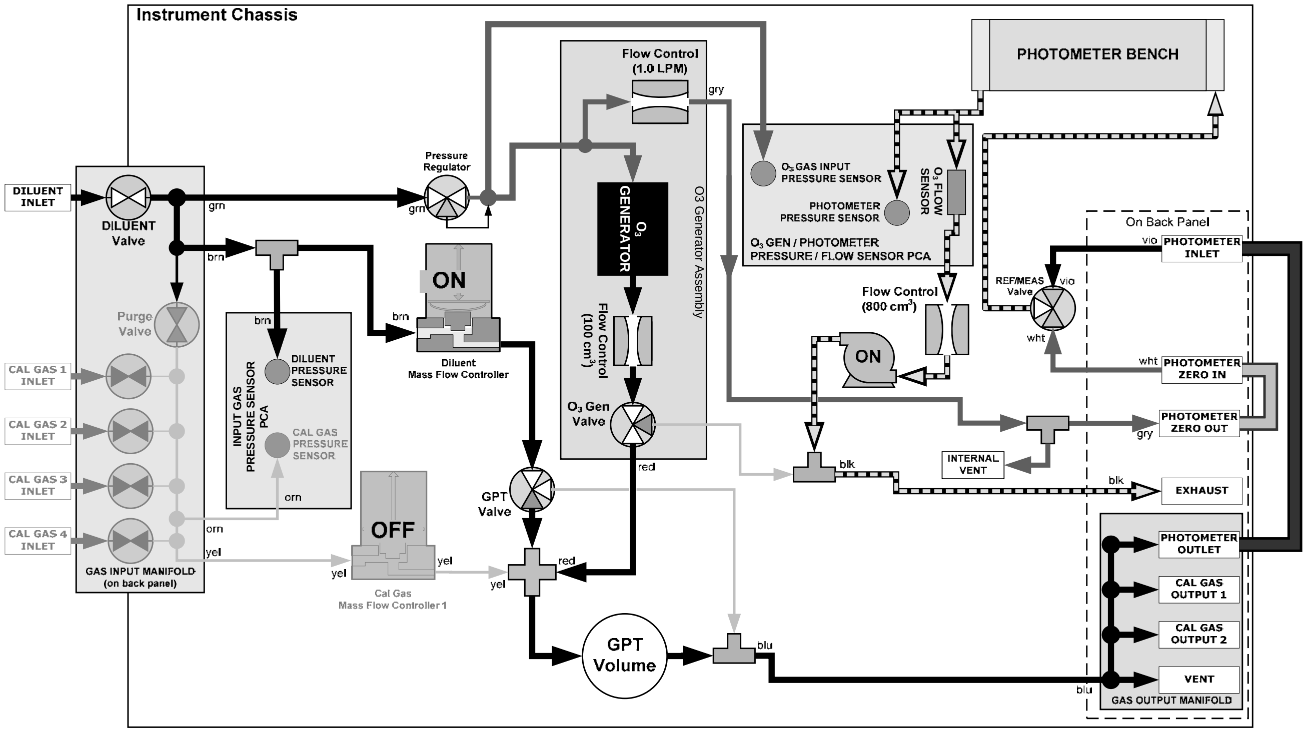


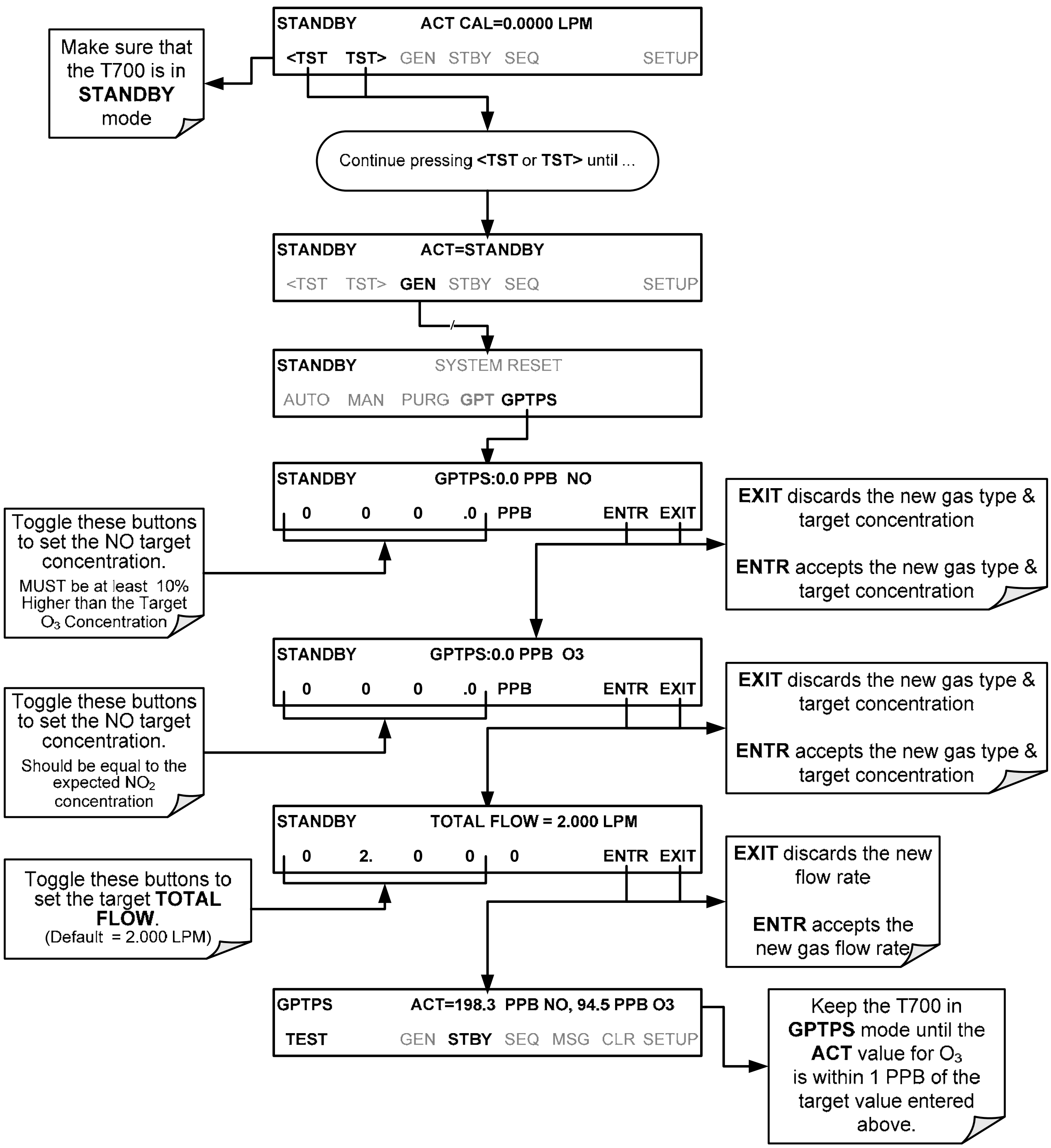
Figure 6-8: Gas Flow through T700 with O_3 Options when in GPTPS Mode

6.4.5.2. Initiating a GPT Pre-Set

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:



6.4.6. GENERATE → PURGE: Activating the T700's Purge Feature

The T700 calibrator's PURGE feature clears residual source gases and calibration mixtures gases from the previous generated steps from the instruments internal pneumatics as well as any external pneumatic lines down stream from the calibrator.

When activated, the **PURGE** feature:

- Opens the Diluent (zero air) inlet valve allowing zero air to flow into the calibrator form its external, pressurized source;
- Adjusts the diluent air mass flow controller (MFC1) to maximum flow;
- Adjusts all of the component gas mass flow controllers installed in the calibrator to maximum flows, 10 SLPM and 100 SCCPM accordingly, to flush out the pneumatic system of the T700.

The **PURGE** air is vented through the VENT port of the rear panel of the instrument (see Figure 3-4).

Table 6-7: Internal Pneumatics During Purge Mode

MODE	VALVES (X = Closed; O = Open)									MFC's			PHOT PUMP
	CYL 1	CYL 2	CYL 3	CYL 4	PURGE	DILUENT	GPT	O_3 GEN	PHOT M/R	CAL1	CAL2[1]	DILUENT	
PURGE	**X**	**X**	**X**	**X**	**O**	**O**	**O**	**O**	Switching	**ON[3]**	**ON[3]**	**ON**	**ON**

[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 instrument with multiple MFC's the CPU chooses which MFC to use depending on the target gas flow requested.

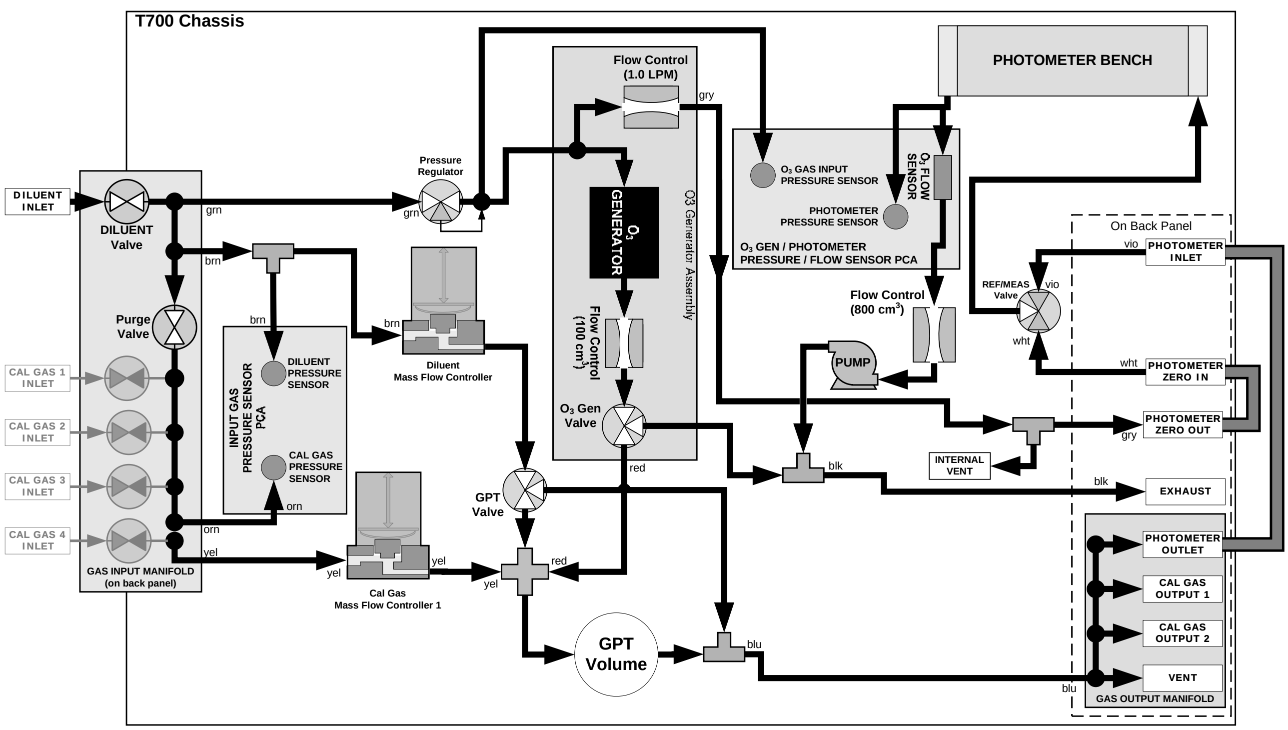
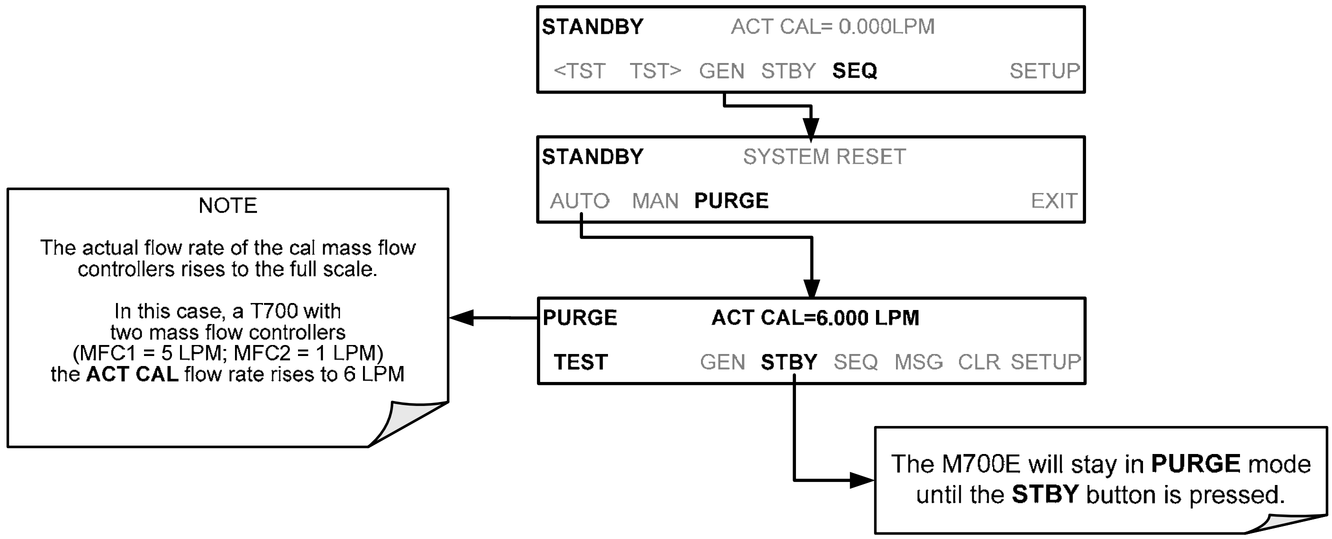


Figure 6-9: Gas Flow through T700 with O_3 Options when in PURGE mode

To activate the **PURGE** feature, press:



CAUTION

THIS PURGE FEATURE DOES NOT STOP AUTOMATICALLY.

THE USER MUST MANUALLY PRESS THE STBY BUTTON TO STOP THE PURGING PROCESS.

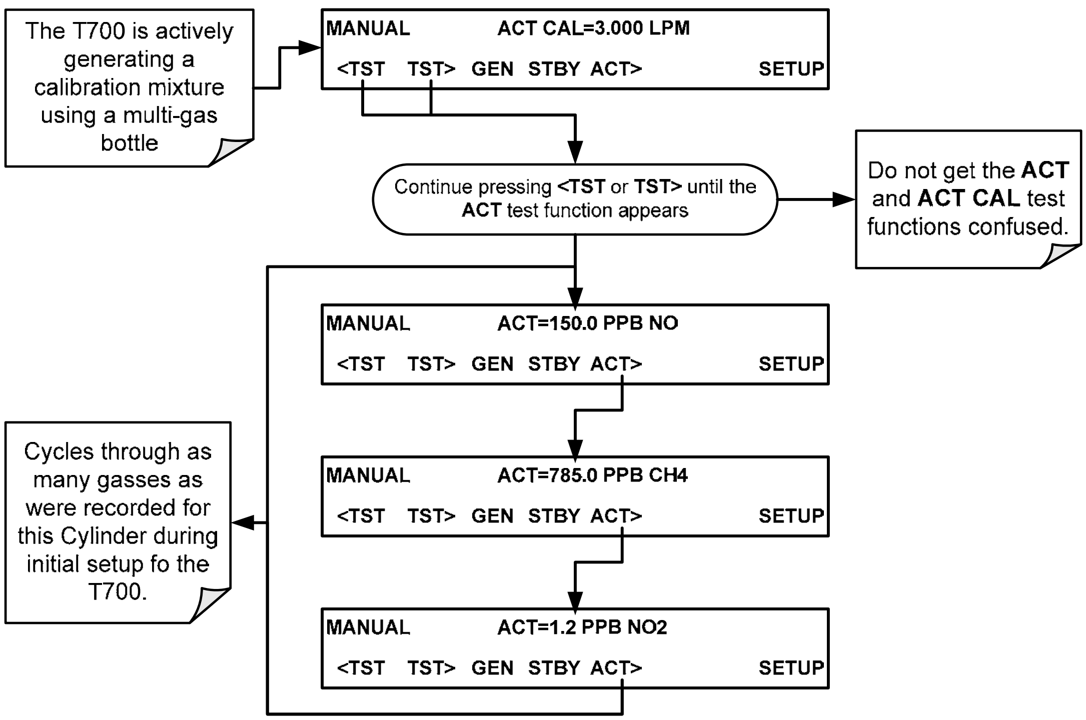
6.4.7. GENERATE →ACT>: VIEWING CONCENTRATIONS GENERATED FROM MULTI-GAS CYLINDERS

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 T700 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 CH_4) using the **GEN → AUTO**, **GEN → MANUAL** buttons or a preprogrammed calibration **SEQUENCE**, press:



NOTE

If the ACT> button only appears if the T700 is generating gas from a multiple-gas cylinder.

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 3.3.8).

6.4.7.1. Using the T700 Calibrator as a O_3 Photometer

If the T700 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.

6.5. AUTOMATIC CALIBRATION SEQUENCES

The T700 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:

- front panel touch screen buttons
- internal timer,
- external digital control inputs
- RS-232 interface
- Ethernet interface
- sub-processes in another sequence

6.5.1. SETUP → SEQ: PROGRAMMING CALIBRATION SEQUENCES

A sequence is a database of single or multiple steps where each single step 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 that must be programmed. They attributes are listed in Table 6-8.

Table 6-8: Automatic Calibration SEQUENCE Set Up Attributes

ATTRIBUTE NAME	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 T700's Digital Control Inputs will initiate the sequence.
CC OUTPUT	Specifies which of the T700's Digital Control Outputs will be set when the sequence is active.
TIMER ENABLE	Enables or disables an internal automatic timer that can initiate sequences using the T700'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 front panels display, as it runs

The types of instruction steps available for creating calibration sequences are listed in Table 6-9.

Table 6-9: 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 front panel.
GPT	Initiates a Gas Phase Titration operation.
GPTPS	Initiates a Gas Phase Titration Preset procedure.
PURGE	Puts the calibrator into **PURGE** mode.
DURATION	Adds a period of time between the previous instruction and the next
EXECSEQ	Calls another sequence to be executed at this time. The calling sequence will resume running when the called sequence is completed. Up to 5 levels of nested sequences can be programmed.
SETCCOUTPUT	Allows the sequence to activate the T700'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 front panel.

NOTE

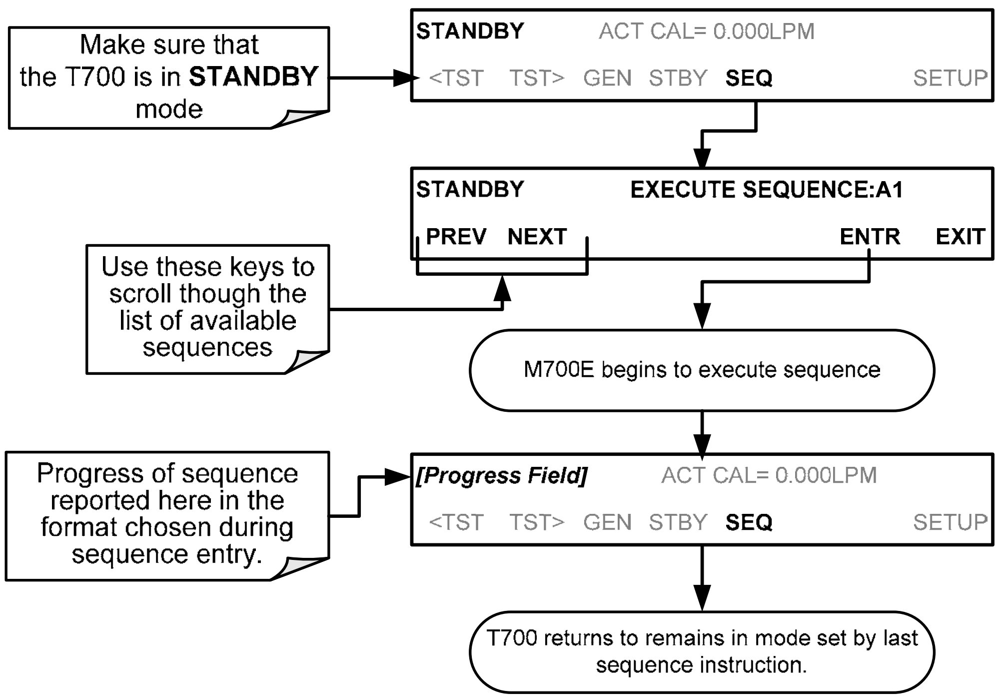
It is generally a good idea to end each calibration sequence with a PURGE instruction followed by an instruction to return the instrument to STANDBY mode.

Even if a PURGE is not included, the last instruction in a sequence should always be an instruction placing the T700 into STANDBY mode.

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.

6.5.1.1. Activating a Sequence from the T700 Front Panel

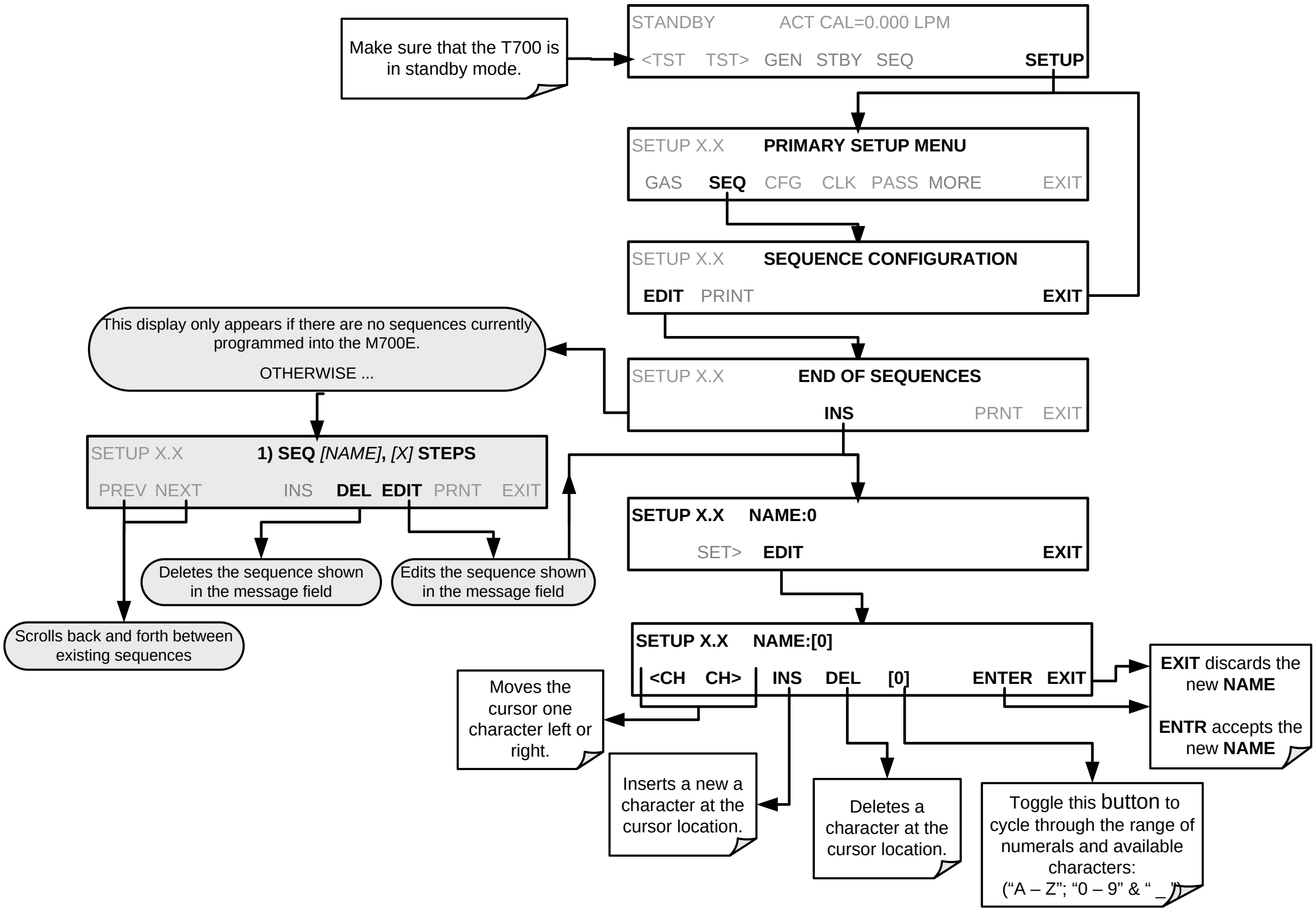
To activate an already programmed sequence from the front panel, press:



6.5.1.2. Naming a Sequence

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 (“_“).

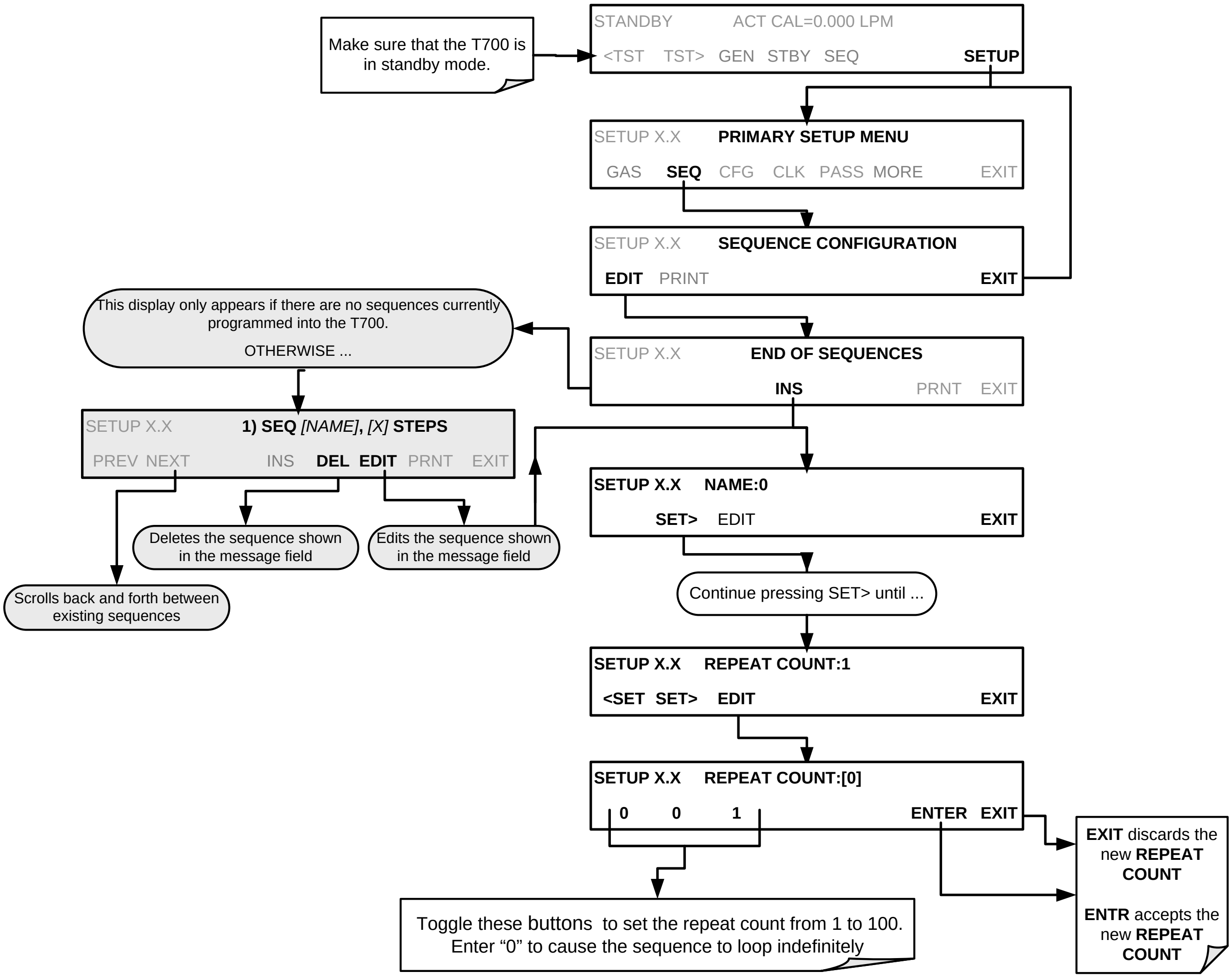
To assign a name to a sequence, press:



6.5.1.3. Setting the Repeat Count for a Sequence

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**.

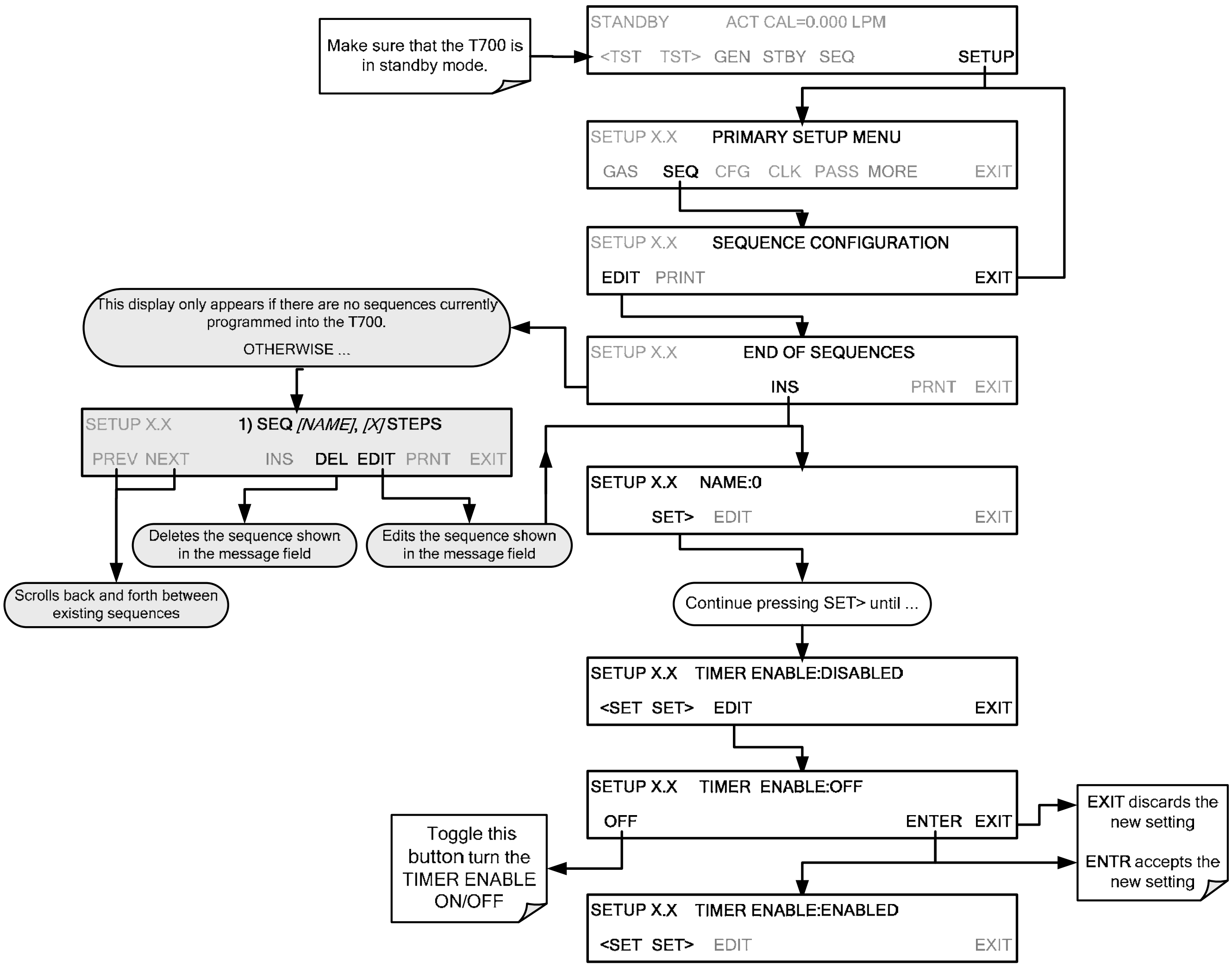
To set the **REPEAT COUNTER**, press:



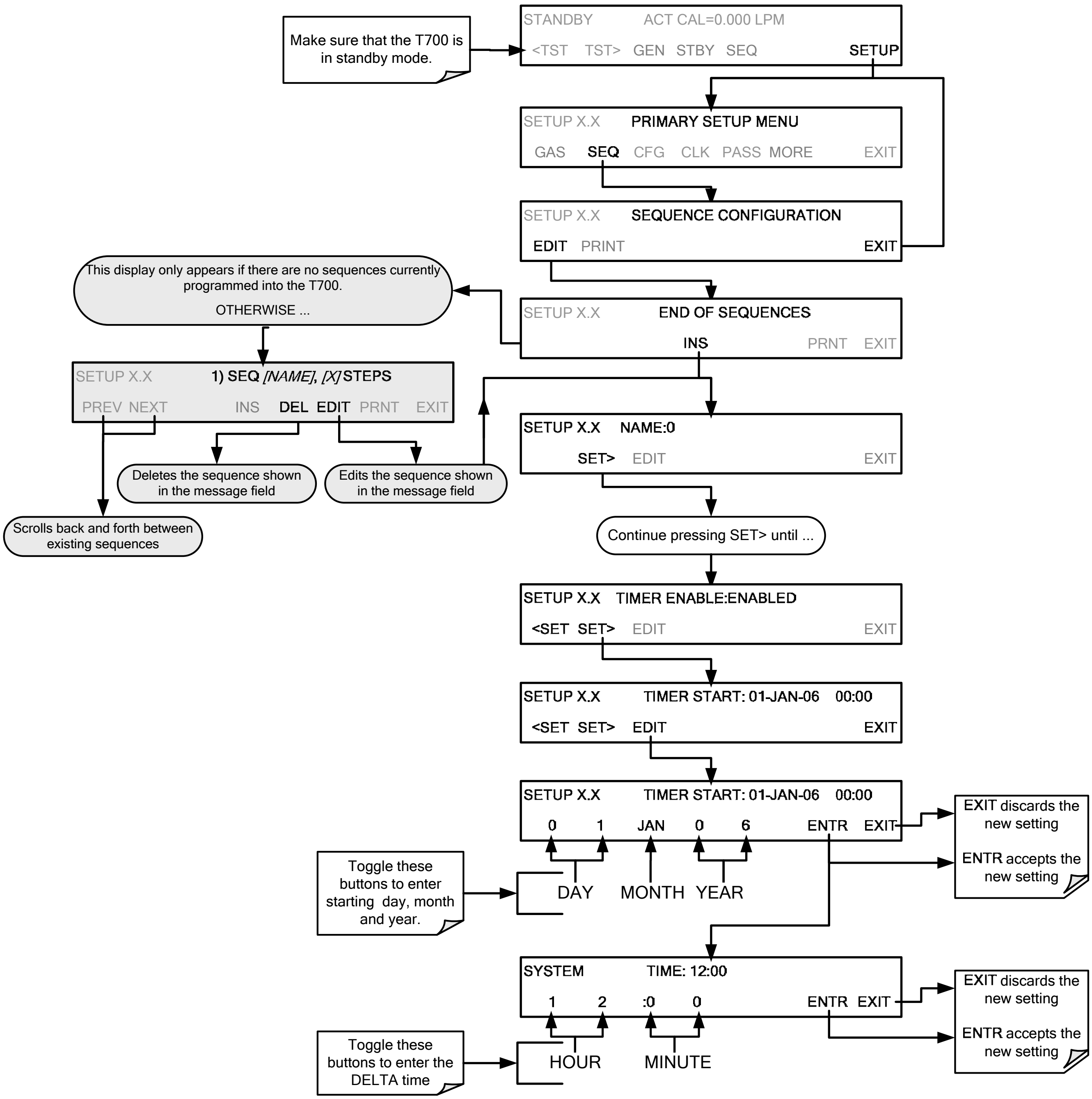
6.5.1.4. Using the T700's Internal Clock to Trigger Sequences

Sequences can be set to trigger based on the T700's internal clock. The sequence can be set up to start at a predetermined date and time. It can also be set to repeat after a predetermined delay time.

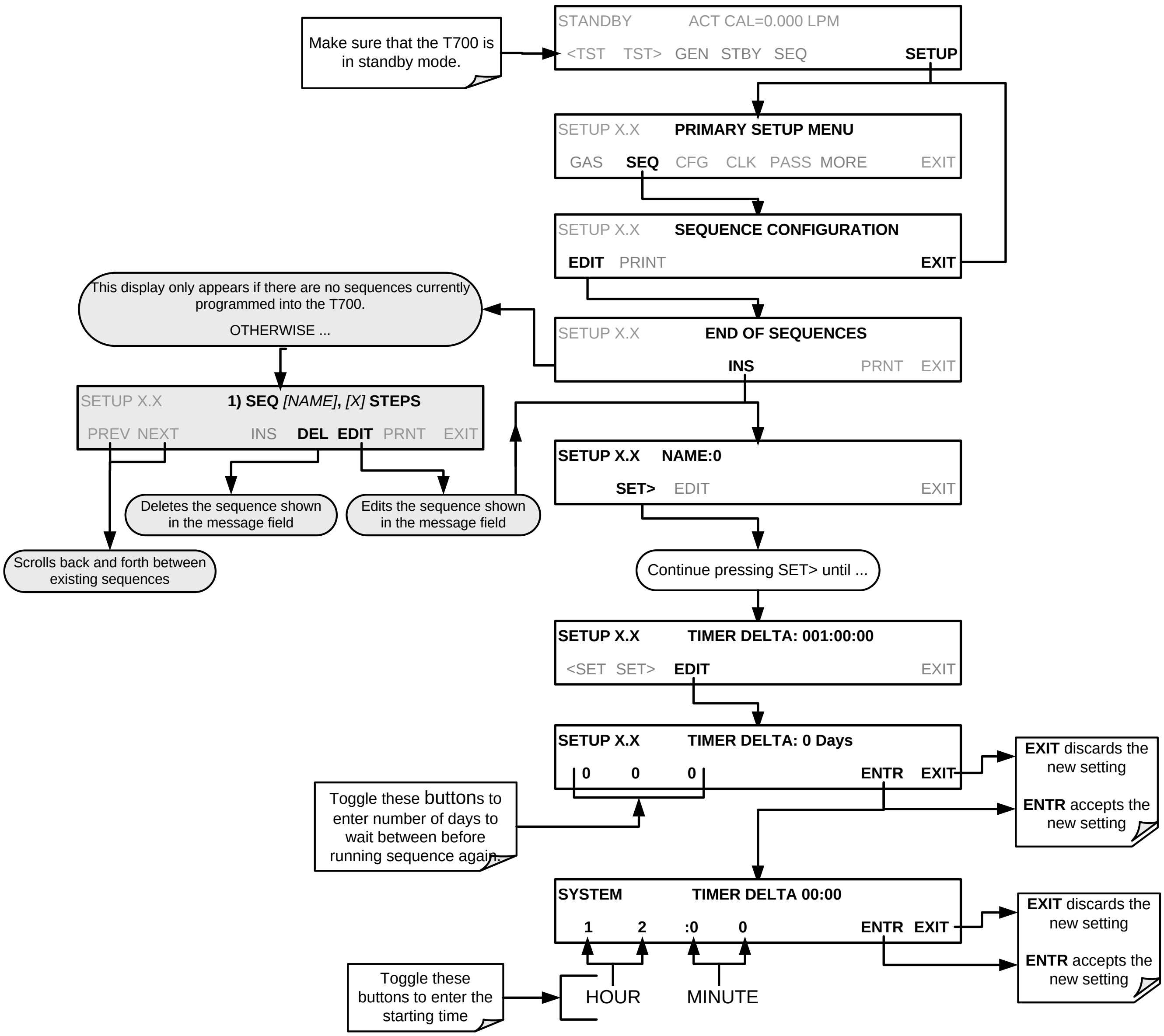
So activate and sequence timer, press:



To specify a starting time for the sequence, press:



To set the delta timer, press:



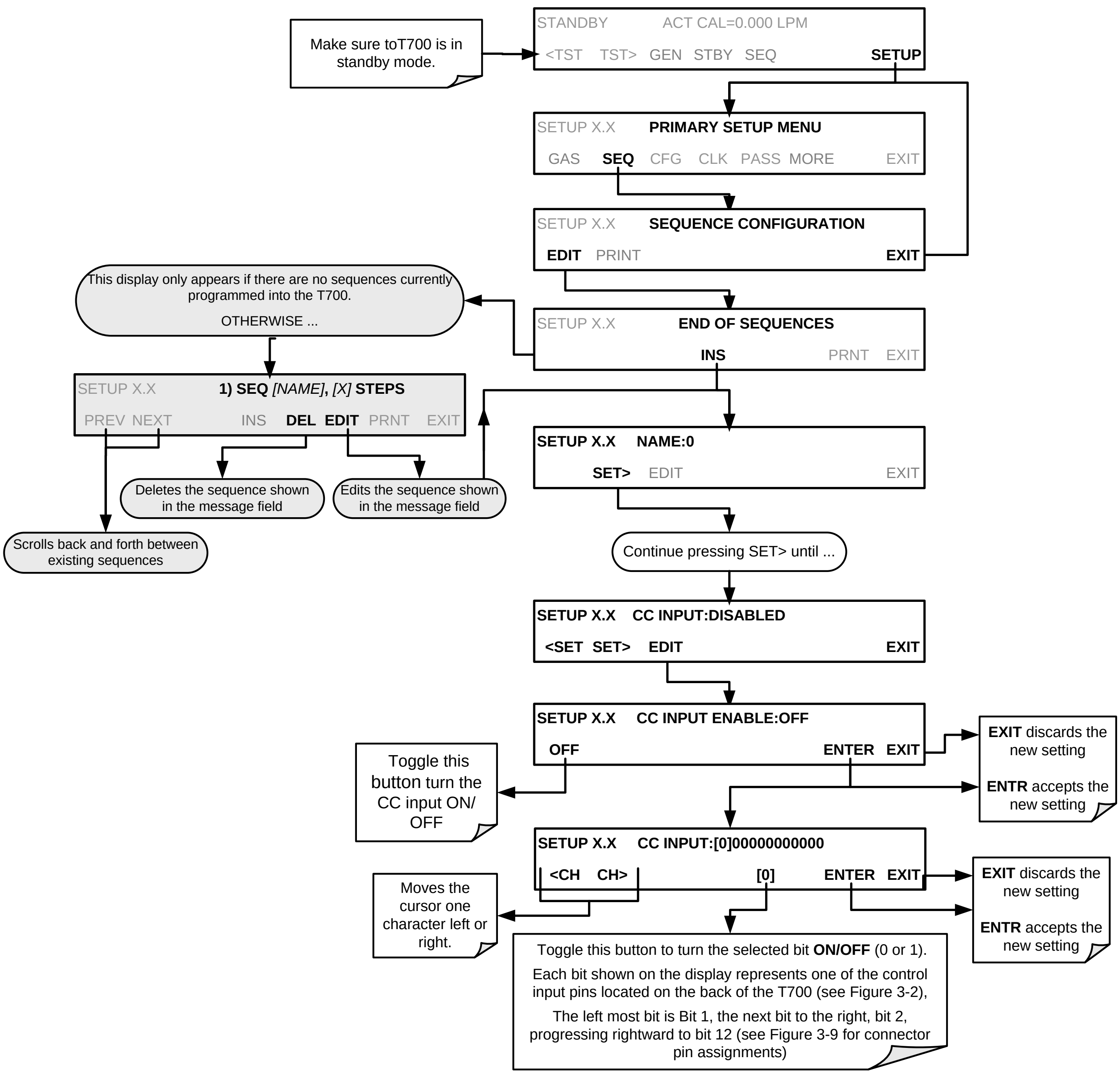
6.5.1.5. Setting Up Control Inputs for a Sequence

The T700 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 datalogger can initiate the calibration sequences.

Each of the T700 calibrator's control outputs is located on the back of the instrument (see Figure 3-4).

- 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:



6.5.1.6. Setting Up Control Outputs for a Sequence

The T700 calibrator's control outputs allow the entire sequence to be triggered from an external source. This feature allows the calibrator to control devices that accept logic-level digital inputs, such as programmable logic controllers (PLC's), dataloggers, or digital relays/valve drivers.

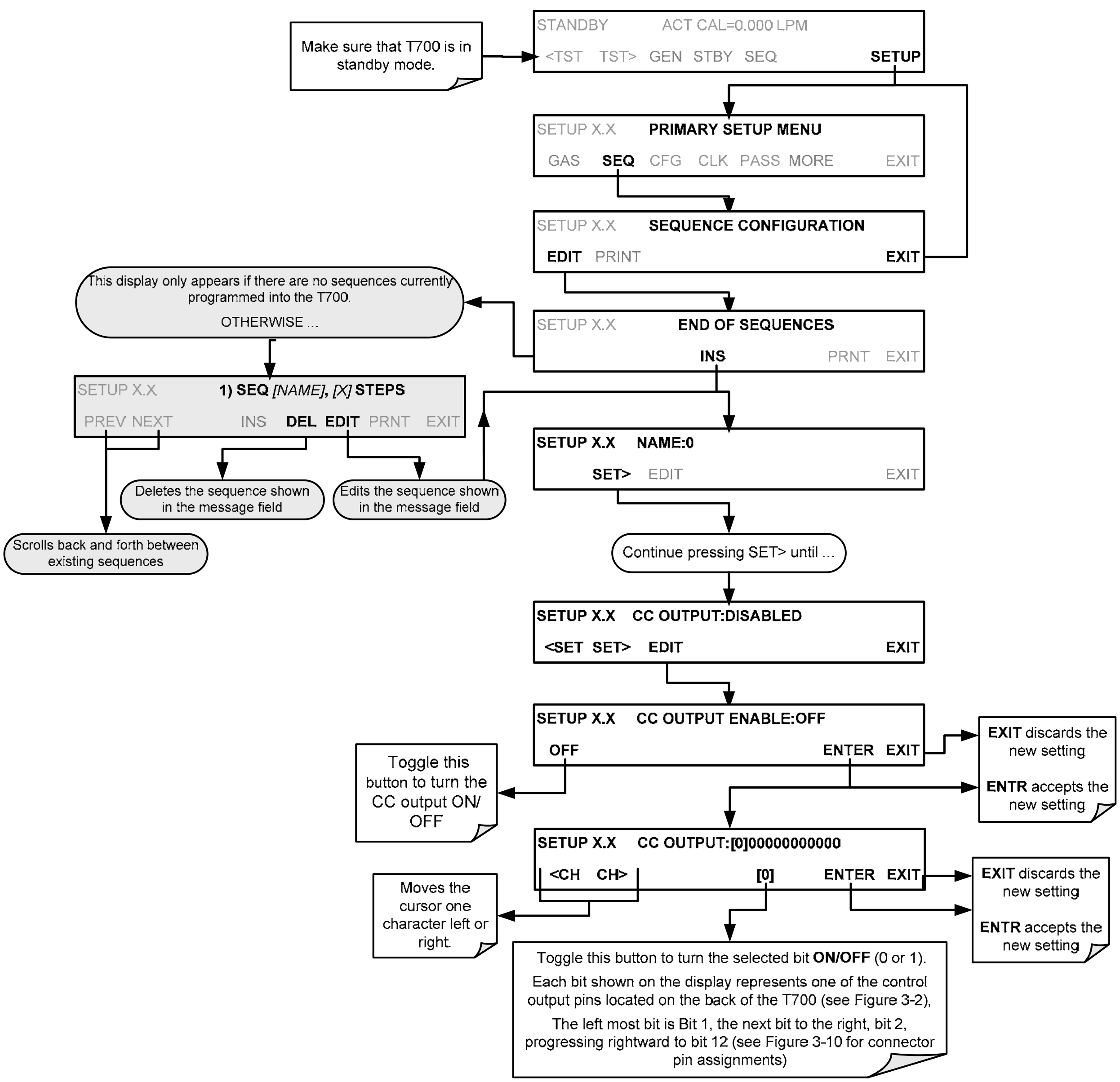
They can be used as:

- 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 6.5.2.8).

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



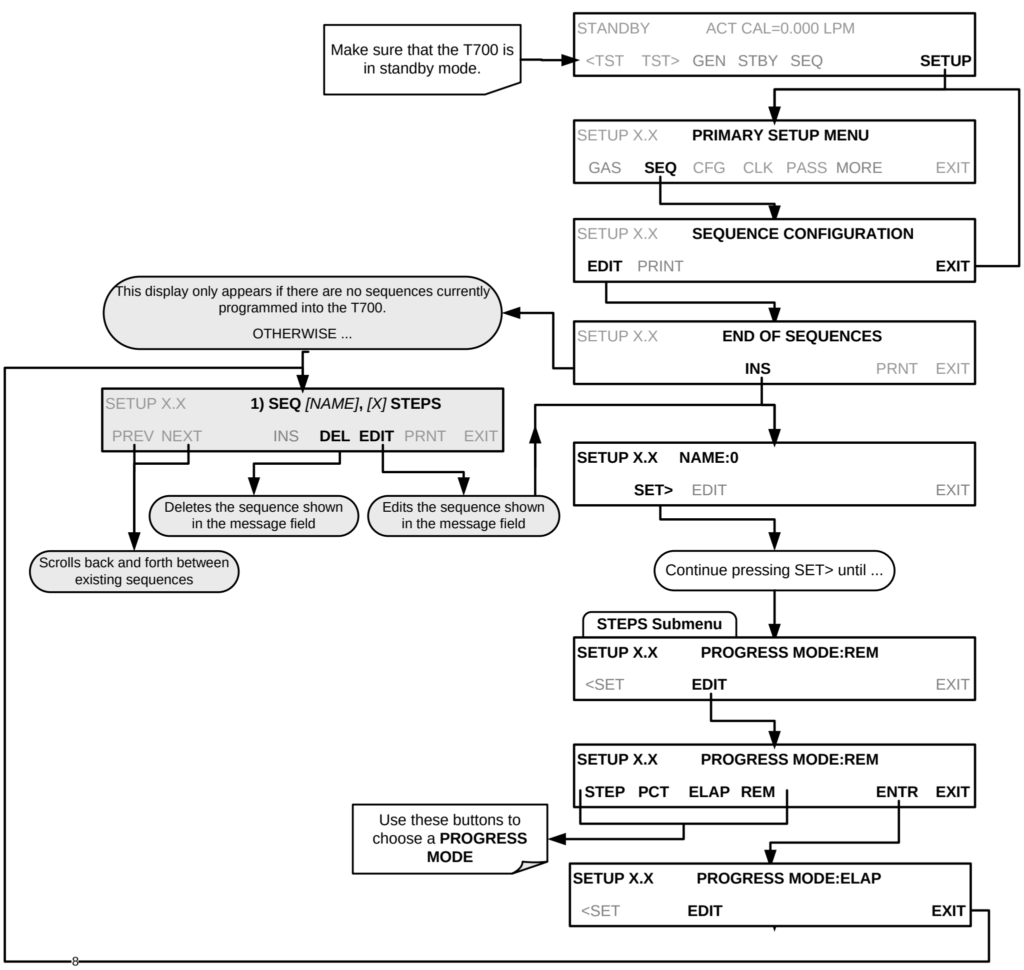
6.5.1.7. Setting the PROGRESS Reporting Mode for the Sequences

As sequences run, the T700 calibrator reports progress by displaying a message in the MODE field of the front panel display (See Figure 3-1). There are several types of report modes available (see Table 6-10).

Table 6-10: Sequence Progress Reporting Mode

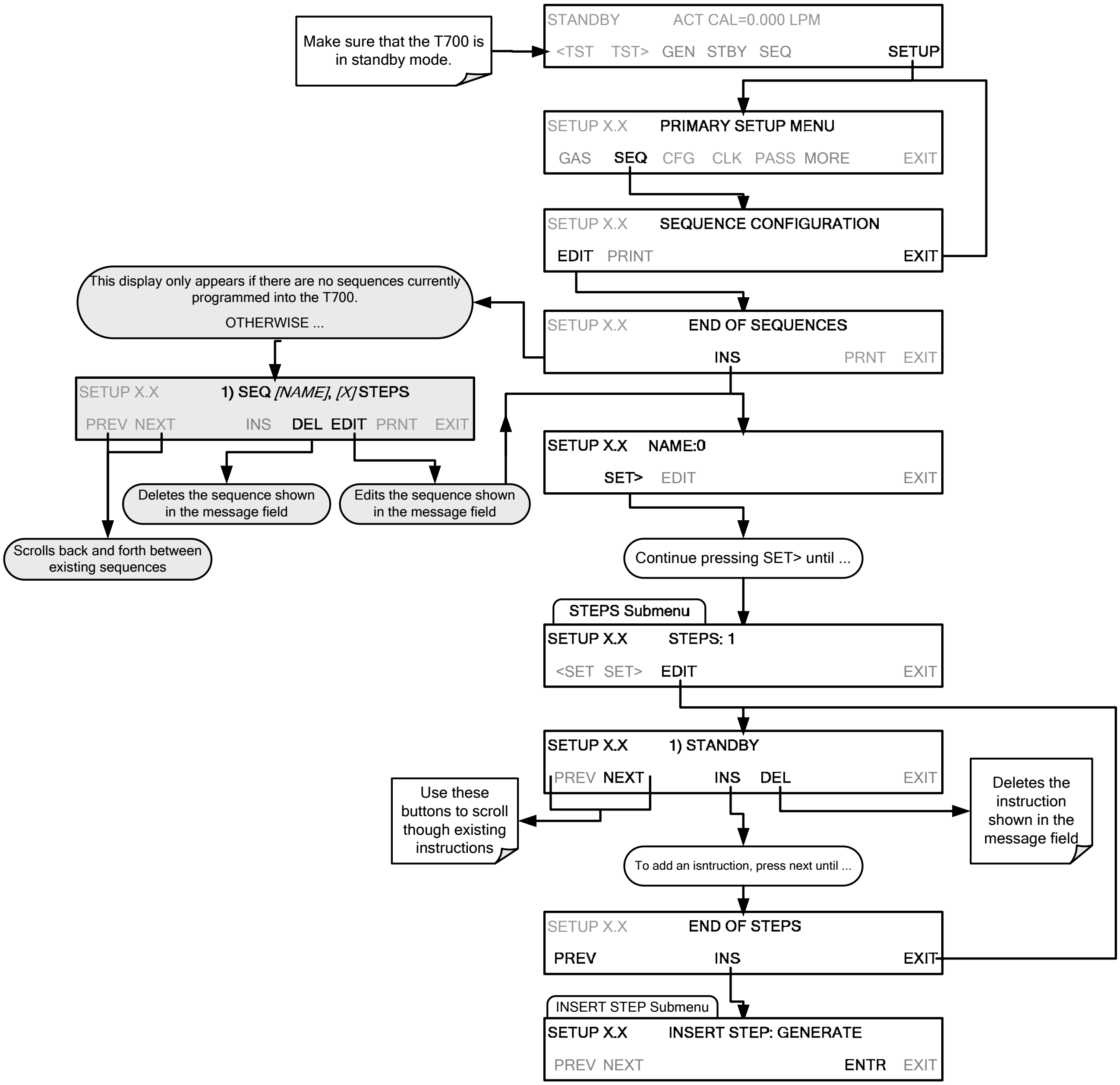
MODE	DESCRIPTION
STEP	• Shows the progress as the sequence name and step number. This is the traditional display. Example: "SO2_Test-2".
PCT	• Shows the progress as a percent (0–100%) of the total sequence duration. Example: "SEQ 48%"
ELAP	• Shows the progress as days, hours, minutes and seconds elapsed, counting from 0. Example (<1 day): "T+01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds elapsed) Example (>=1 day): "T+1d30:25" (i.e. 1 day, 30 hours, 25 minutes elapsed)
REM	• Shows the progress as days, hours, minutes, and seconds remaining, counting down to 0. Example (<1 day): "T–01:30:25" (i.e. 1 hour, 30 minutes, 25 seconds remaining) Example (>=1 day): "T–1d30:25" (i.e. 1 day, 30 hours, 25 minutes remaining)

To select a PROGRESS report mode, press:



6.5.2. ADDING SEQUENCE STEPS

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

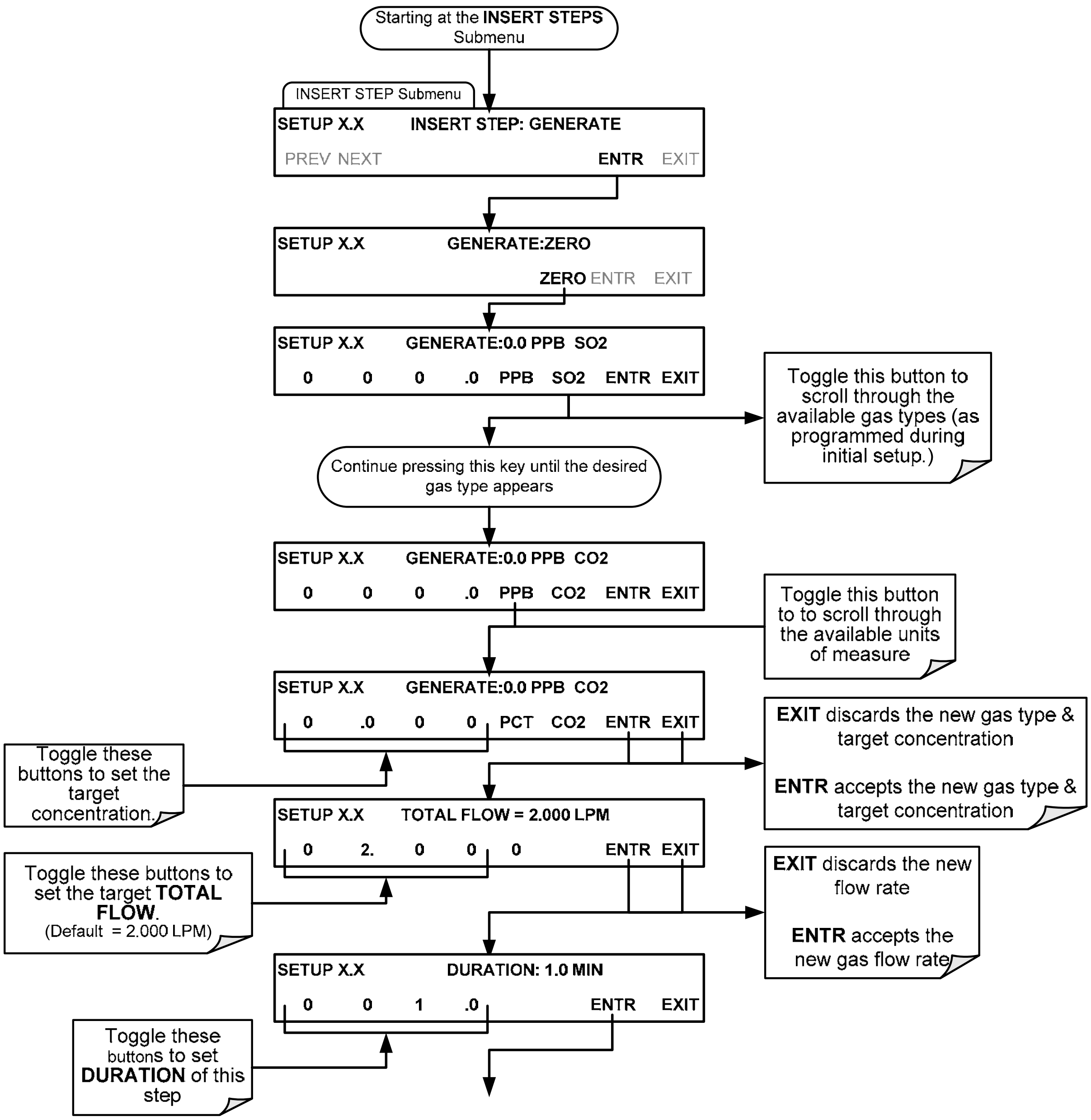


6.5.2.1. The GENERATE Step

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

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

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



NOTE

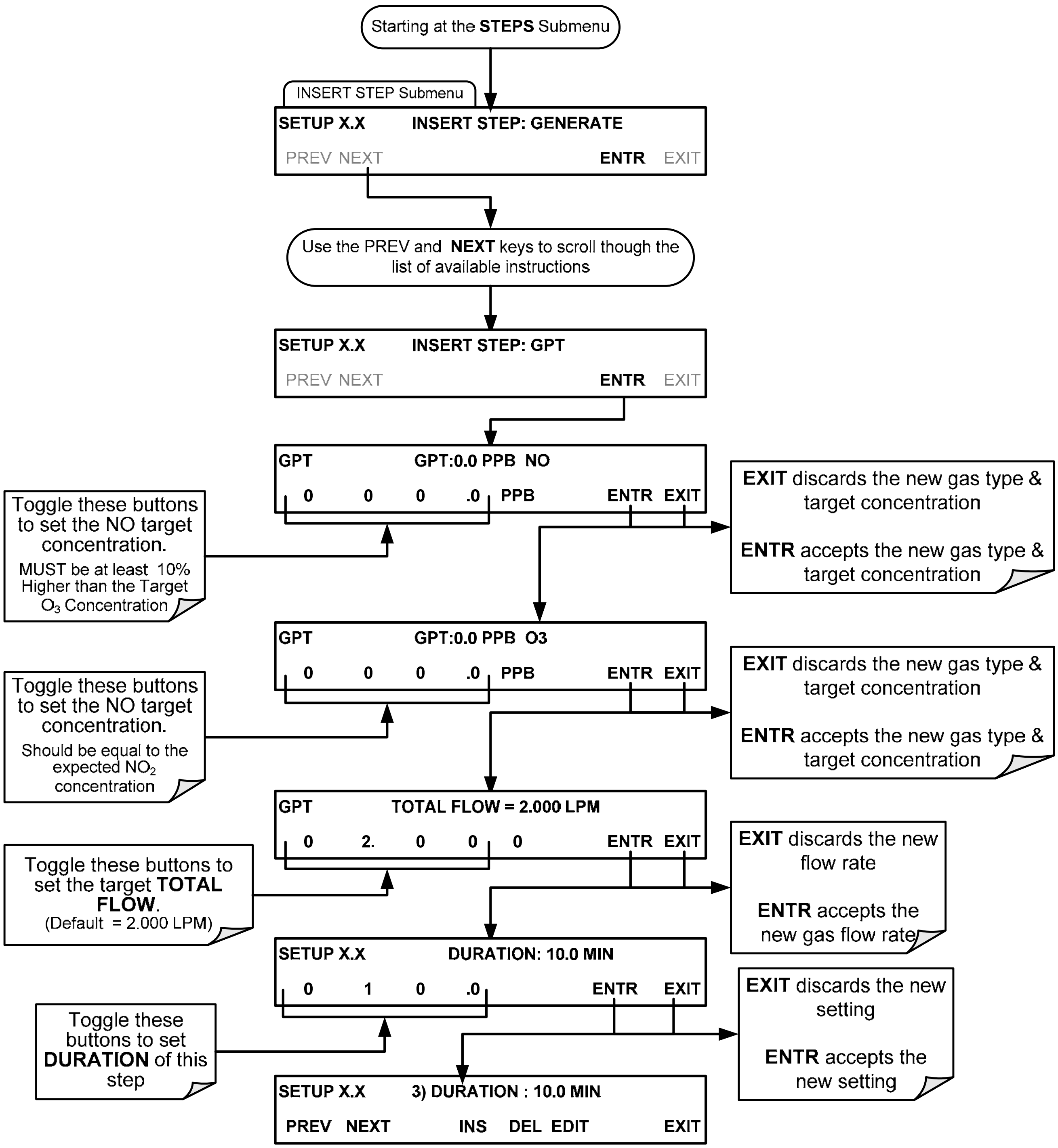
If the user attempts to generate a source gas type that has not been entered into the T700's gas library, the sequence will freeze and after a certain time-out period, stop running.

6.5.2.2. The GPT Step

This step operates and is programmed similarly to the **GENERATE →GPT** (see Section 6.4.4 for information on choosing the correct input values for this step)**.**

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

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

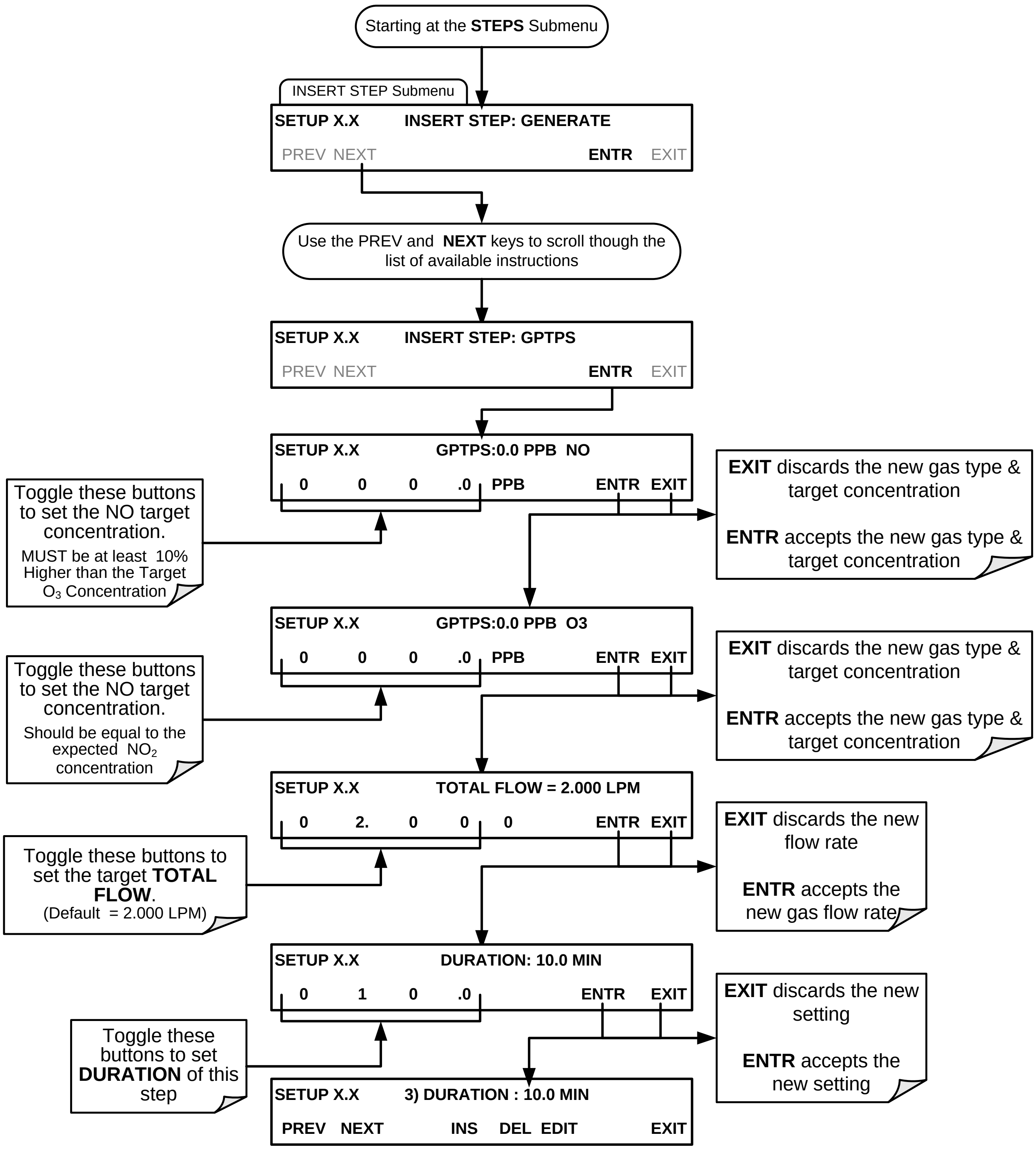


6.5.2.3. The GPTPS Step

This step operates and is programmed similarly to the **GENERATE →GPTPS** (see Section 6.4.5 for information on choosing the correct input values for this step)**.**

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

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

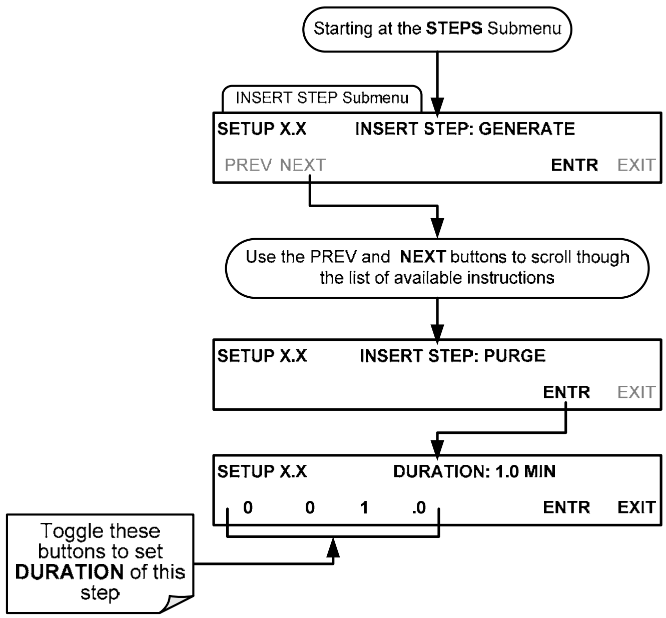


6.5.2.4. The PURGE Step

This step places the T700 into **PURGE** mode.

At the end of the programming sequence, the T700 firmware will automatically insert a **DURATION** step that needs to be defined.

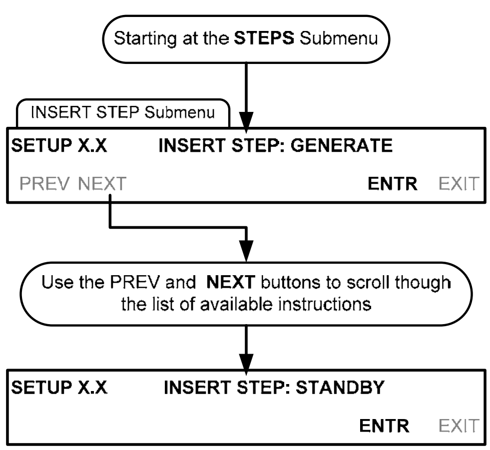
To insert a **PURGE** step into a sequence, press:



6.5.2.5. The STANDBY Step

The **STANDBY** step places the T700 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:

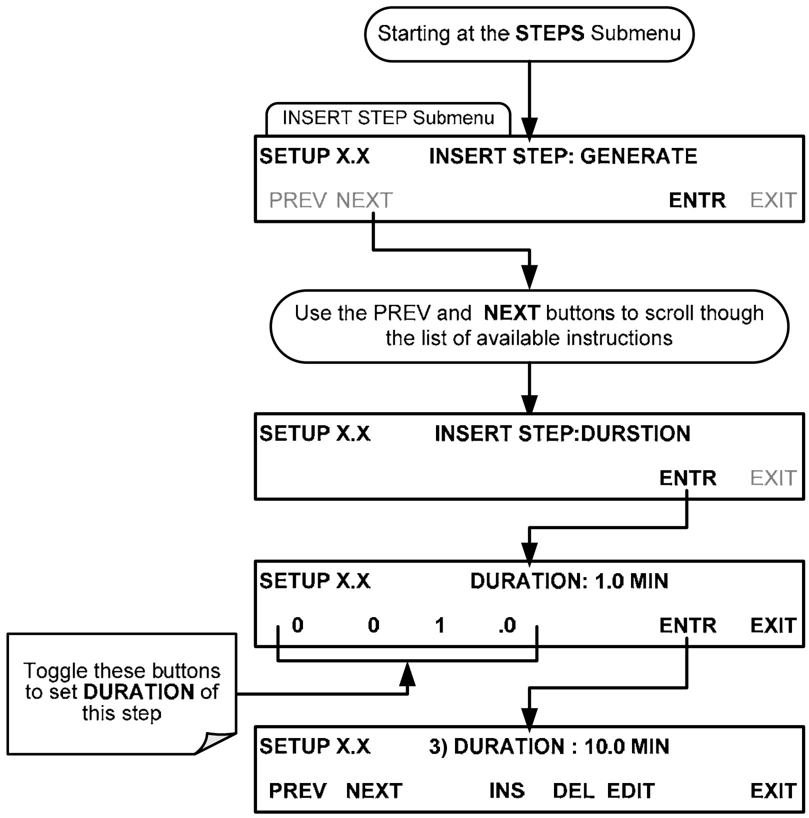


6.5.2.6. The DURATION Step

The duration step causes the T700 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.

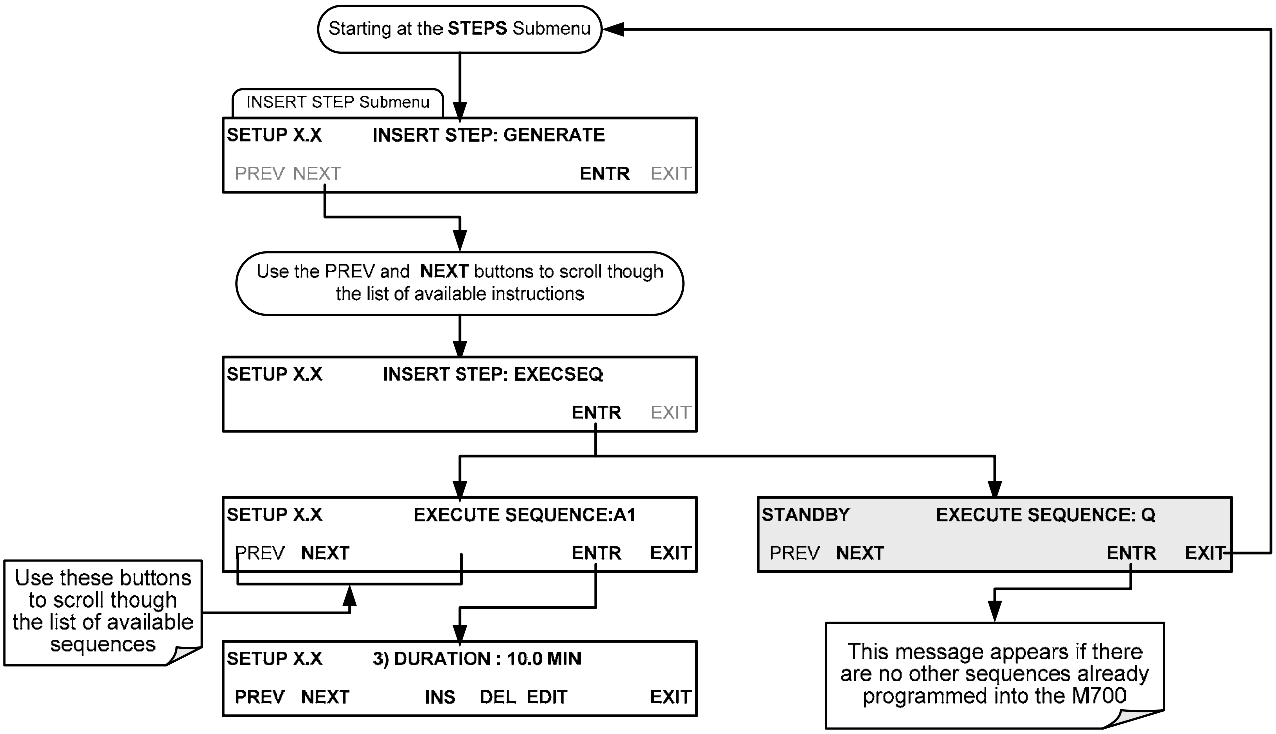
To insert a **DURATION** step into a sequence, press:



6.5.2.7. The EXECSEQ Step

The **EXECSEQ** step allows the sequence to call another, already programmed sequence. 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.

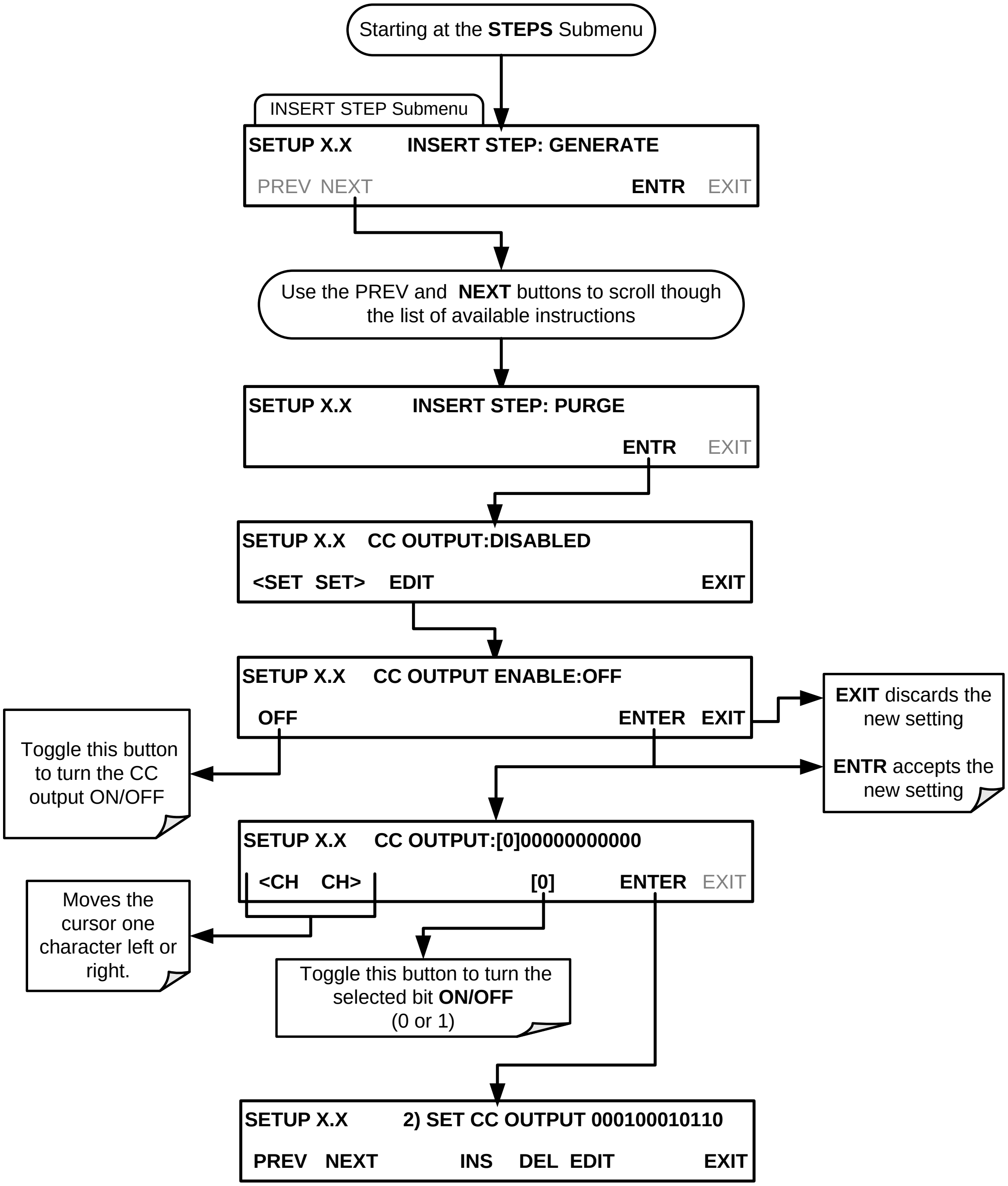
To insert an **EXECSEQ** step into a sequence, press:



6.5.2.8. The CC OUTPUT Step

This instruction causes the sequence to set or reset the T700'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.

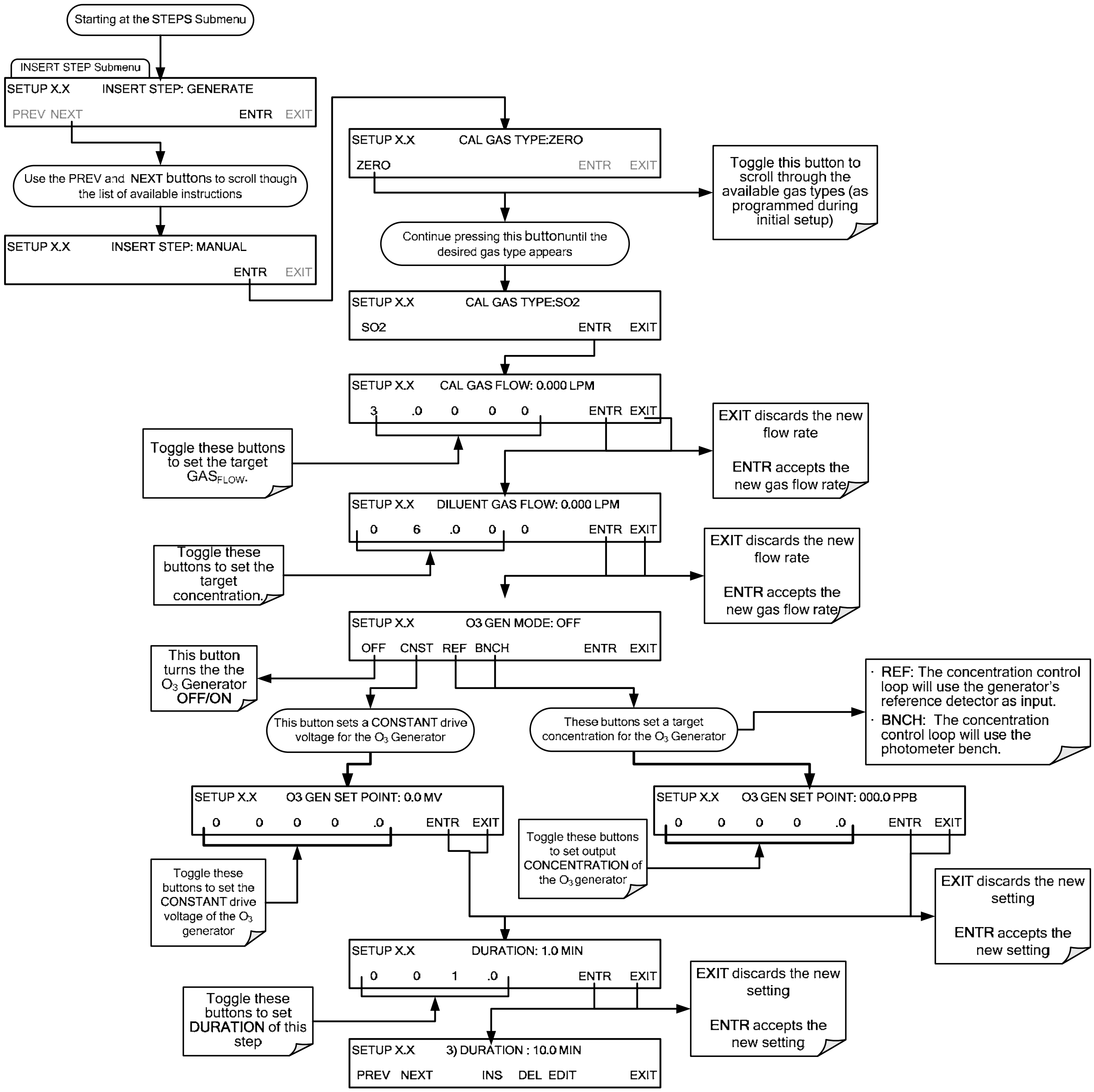
To insert a **CC OUTPUT** step into a sequence, press:



6.5.2.9. The MANUAL Gas Generation Step

The **MANUAL** step causes the T700 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 T700 firmware will automatically insert a DURATION step that needs to be defined.

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

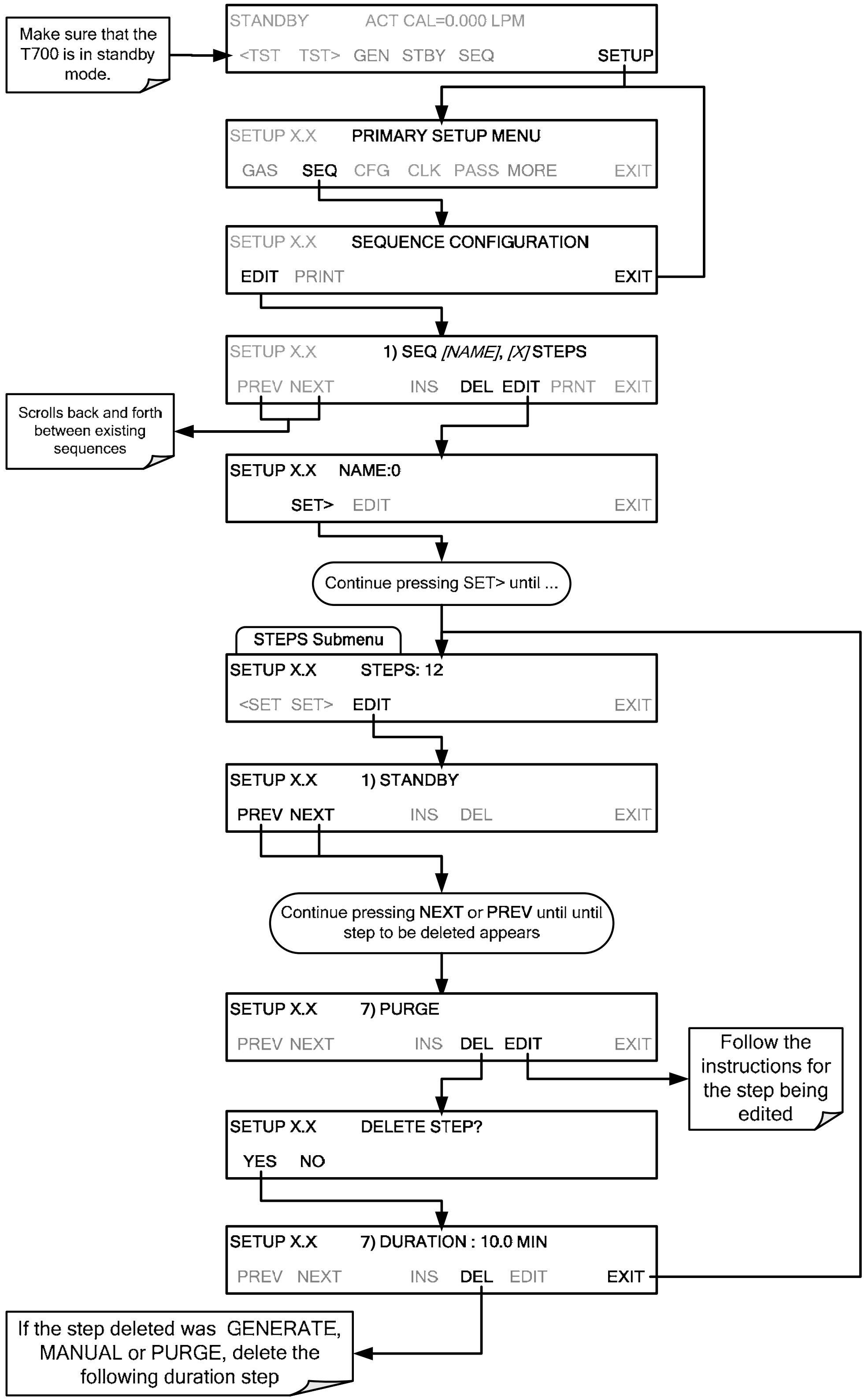


NOTE

If the user attempts to generate a source gas type that has not been entered into the T700's gas library, the sequence will freeze and after a certain time-out period, stop running.

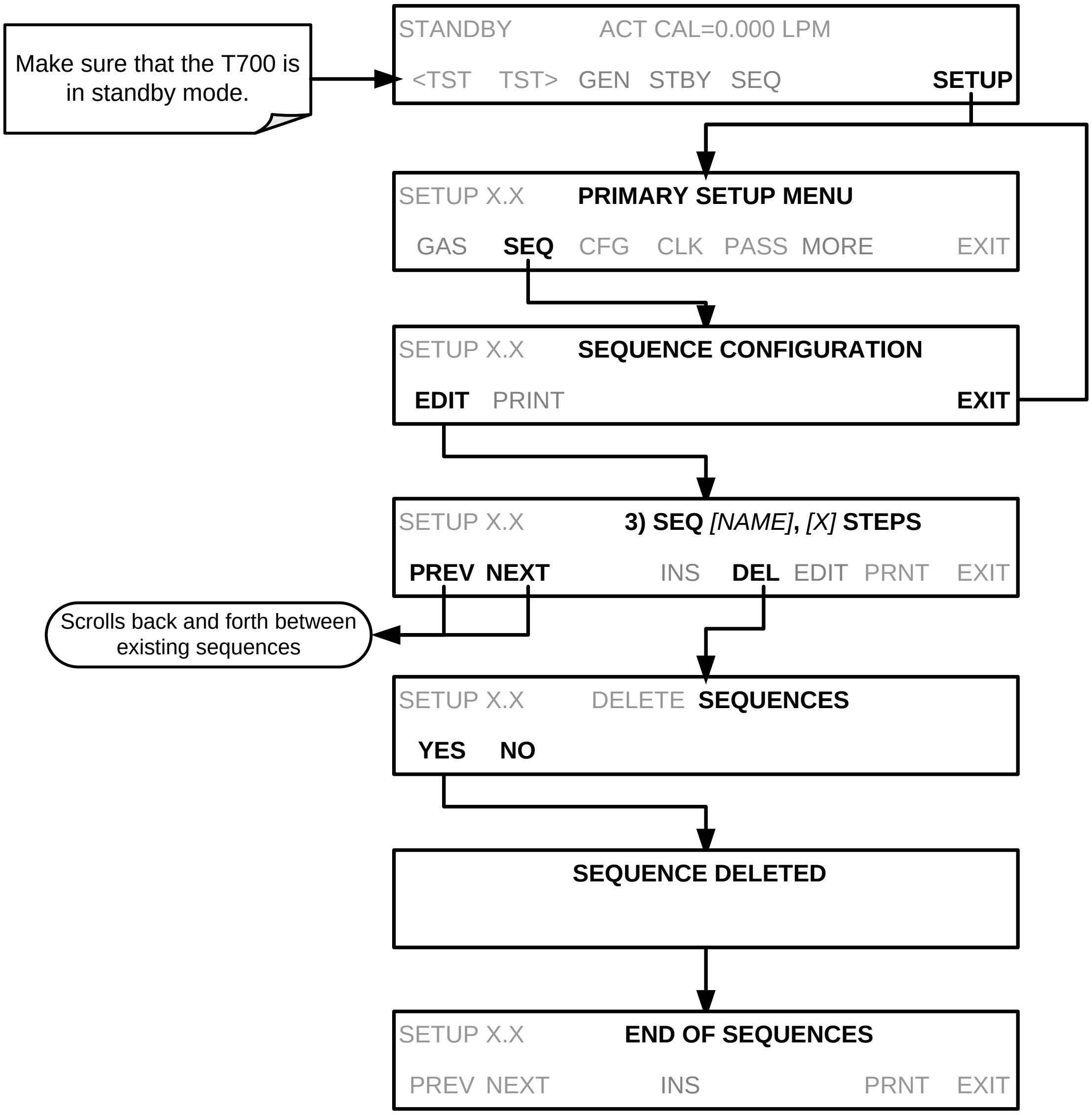
6.5.2.10. Deleting or Editing an Individual Step in a Sequence

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



6.5.3. DELETING A SEQUENCE

To delete a sequence from the T700 calibrator's memory, press:

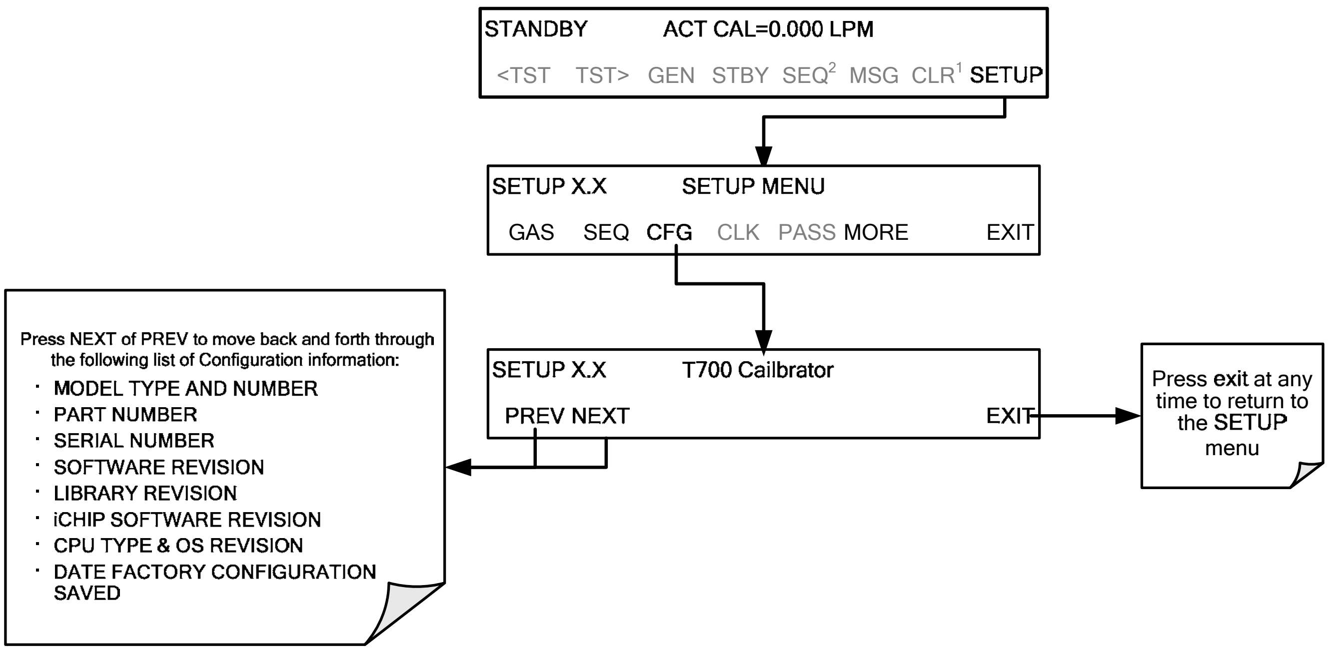


6.6. SETUP → CFG

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 customer service.

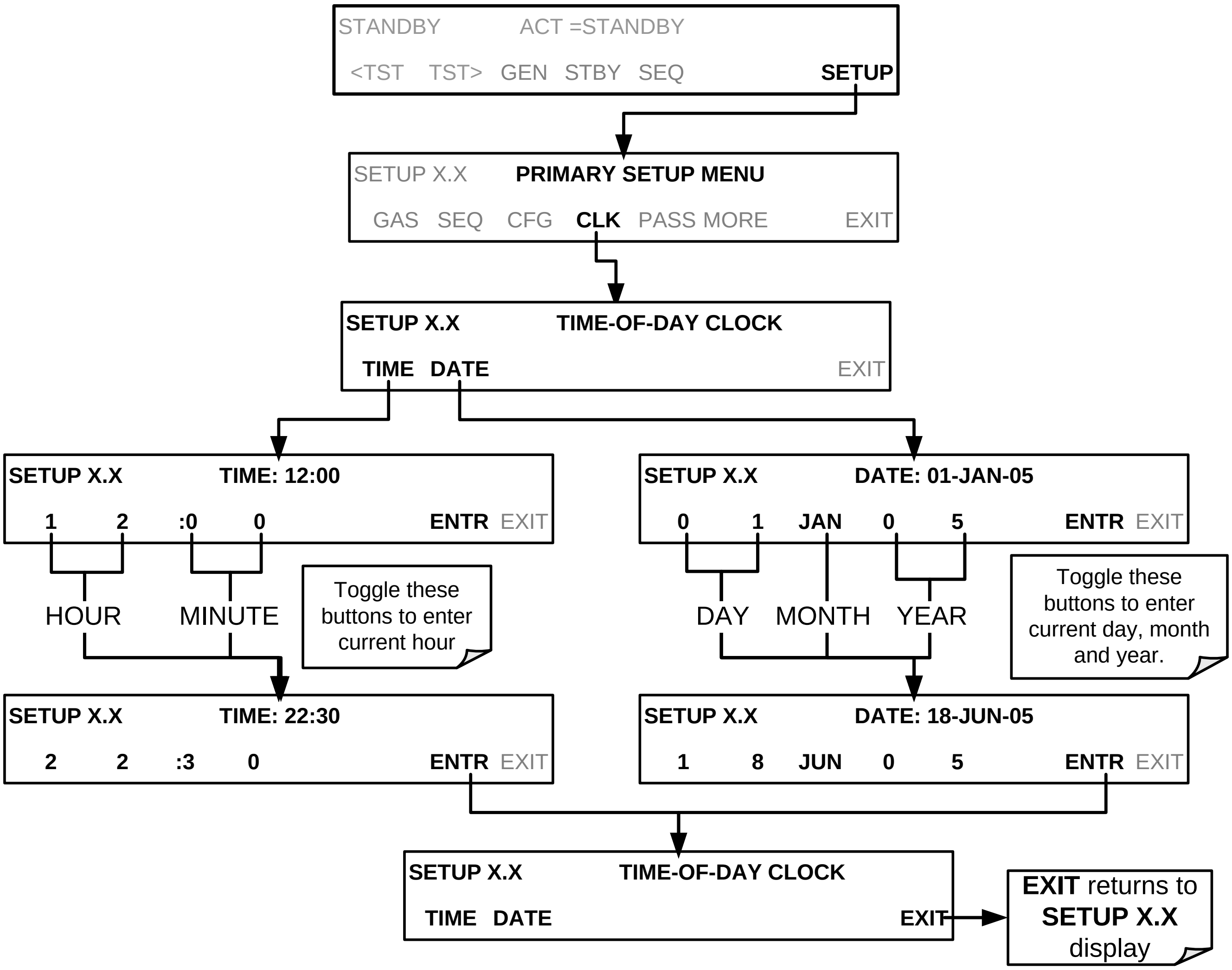
Special instrument or software features or installed options may also be listed here.



6.7. SETUP → CLK

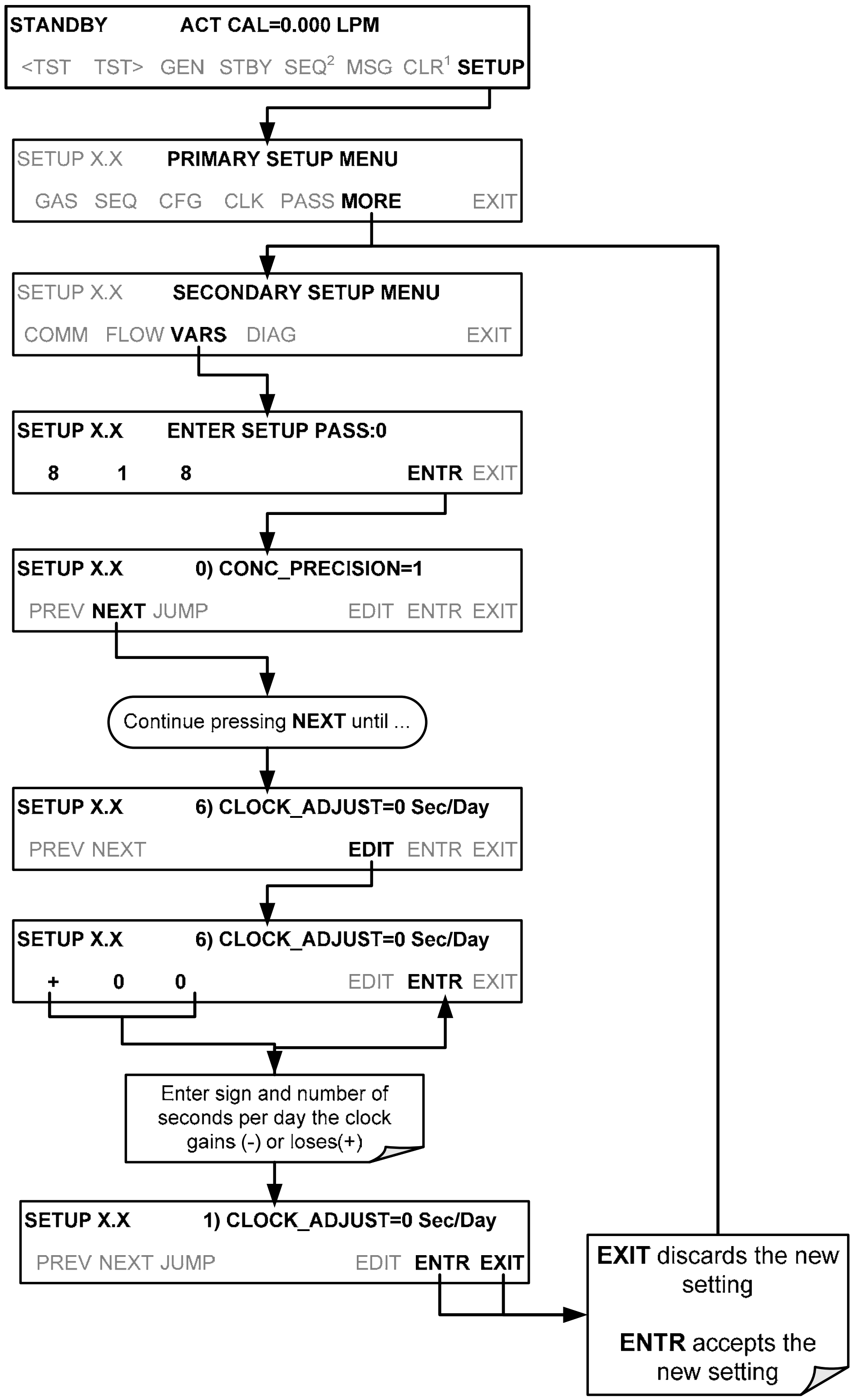
6.7.1. SETTING THE INTERNAL CLOCK'S TIME AND DAY

The T700 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:



6.7.2. 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:



6.8. SETUP → PASS

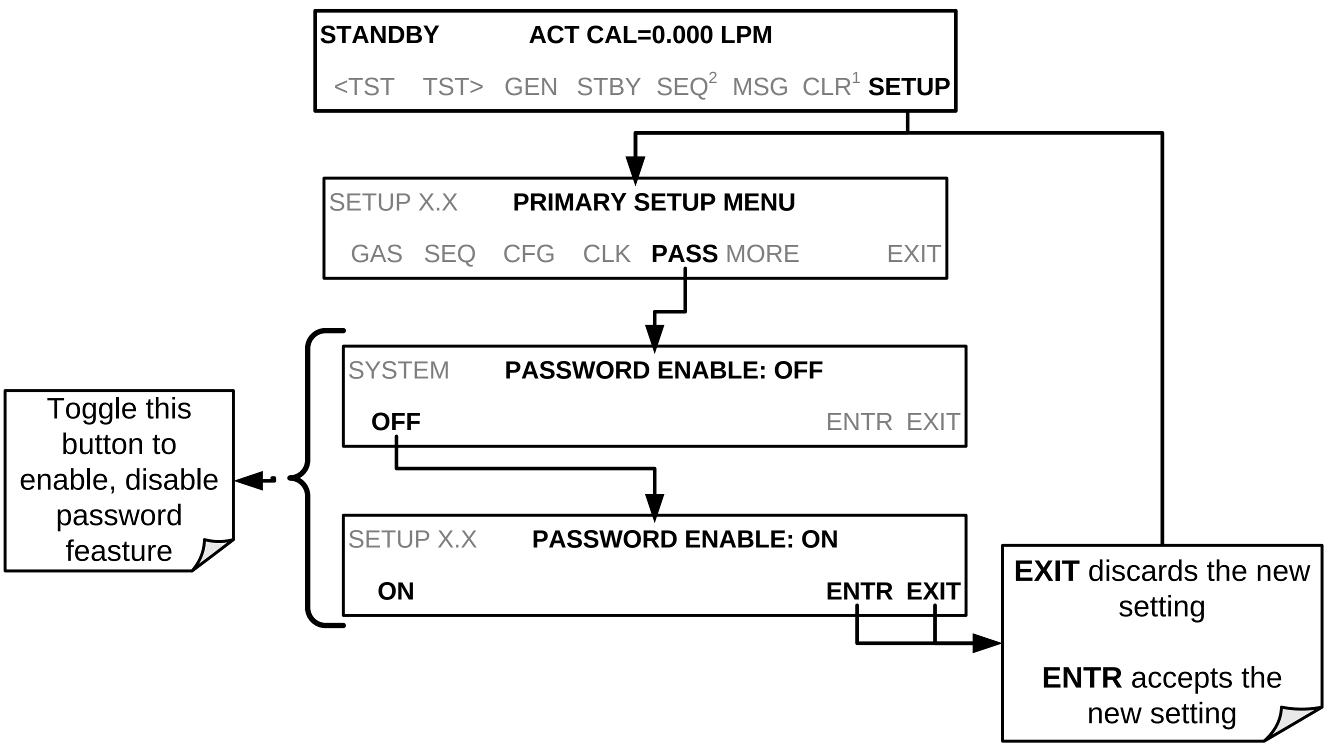
The T700 provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function is requested.

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.

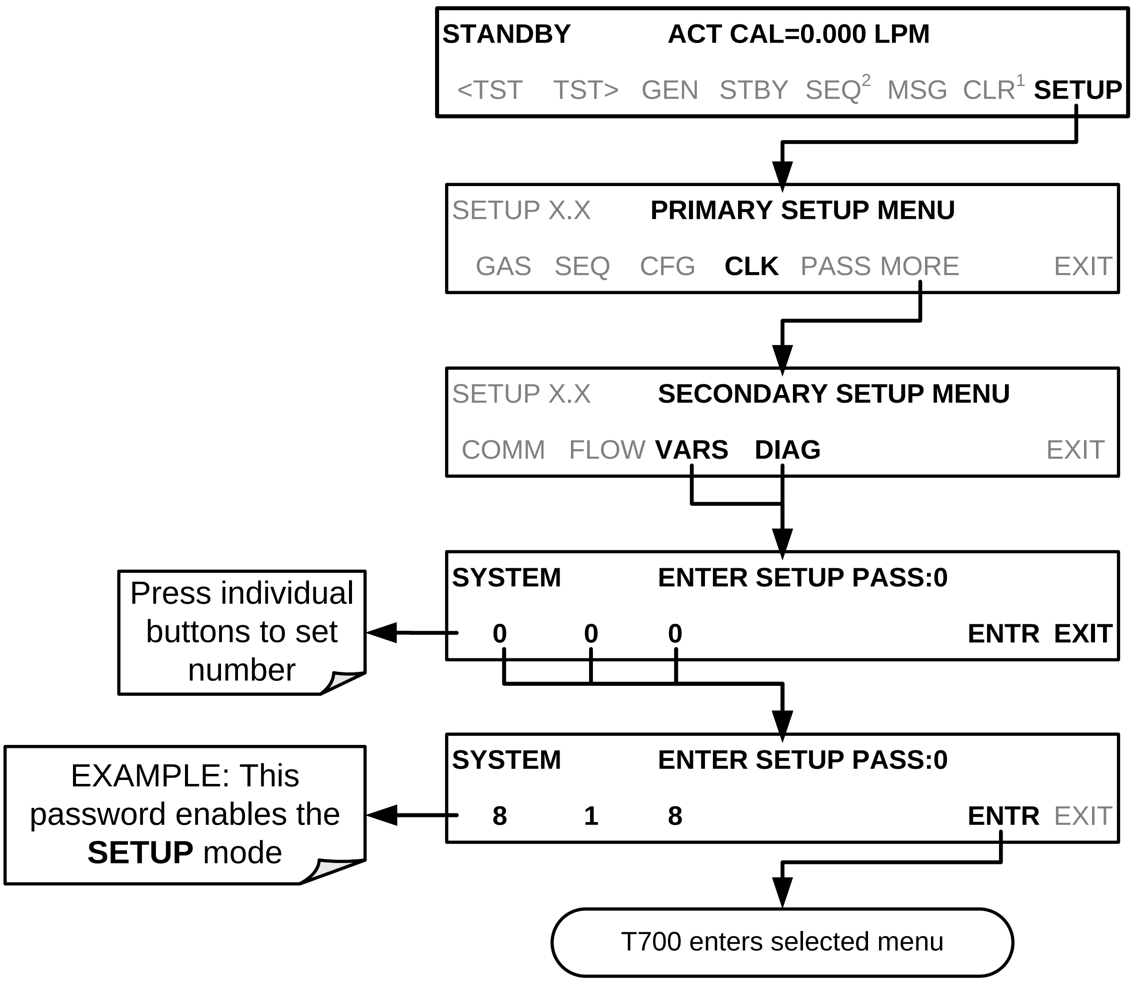
Table 6-11: Password Levels

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 if passwords are disabled, but it displays the default password (818) upon entering these menus. The user only has to press ENTR to access the password-protected menus but does not have to enter the required number code.

6.9. SETUP → DIAG → TEST CHAN OUTPUT: USING THE TEST CHANNEL ANALOG OUTPUT

The T700 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 6-13 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 rear panel of the instrument are:

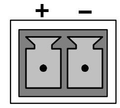


Figure 6-10: T700 the TEST CHANNEL Connector

6.9.1. CONFIGURING THE TEST CHANNEL ANALOG OUTPUT

6.9.1.1. The Analog I/O Configuration Submenu.

Table 6-12 lists the analog I/O functions that are available in the T700 calibrator.

Table 6-12: DIAG – Analog I/O Functions

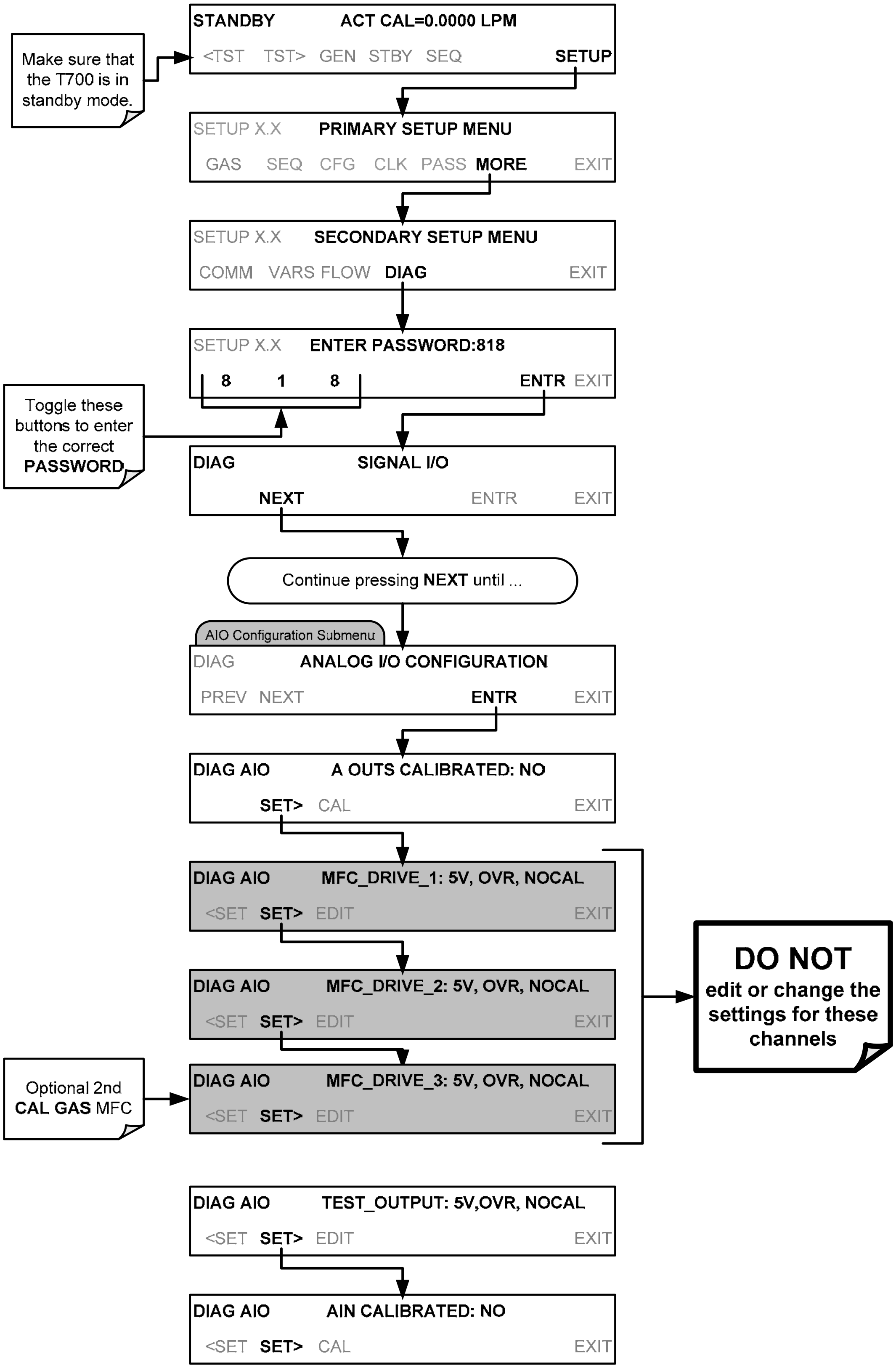
SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
MFC_DRIVE_1	**These channels are used by the T700 calibrator internally as drive voltages for instruments with analog MFC's.** **DO NOT alter the settings 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:

1. Choosing a **TEST CHANNEL** function to be output on the channel.
2. Selecting a signal level that matches the input requirements of the recording device attached to the channel.
3. Determining if the over-range feature is needed and turn it on or off accordingly.
4. Adding a bipolar recorder offset to the signal if required (Section 6.9.1.5).

5. Calibrating the output channel. This can be done automatically or manually for each channel (see Section 6.9.2).

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



6.9.1.2. Selecting a Test Channel Function to Output

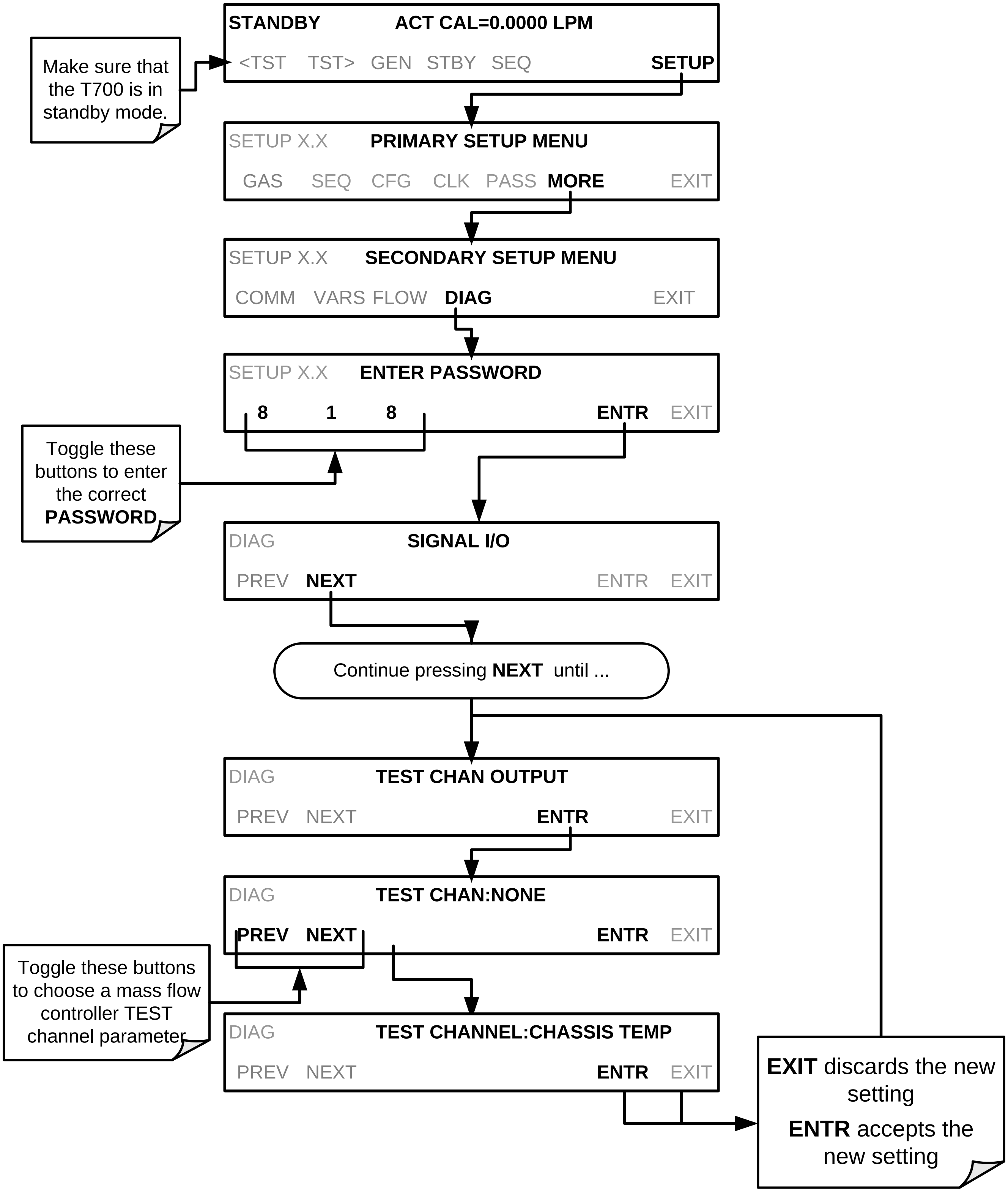
The Test Functions available to be reported are listed on Table 6-13:

Table 6-13: Test Channels Functions available on the T700'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
O3 GEN REF	The raw output of the O_3 generator's reference detector	0 mV	5000 mV
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 T700'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 Front Panel Display.

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



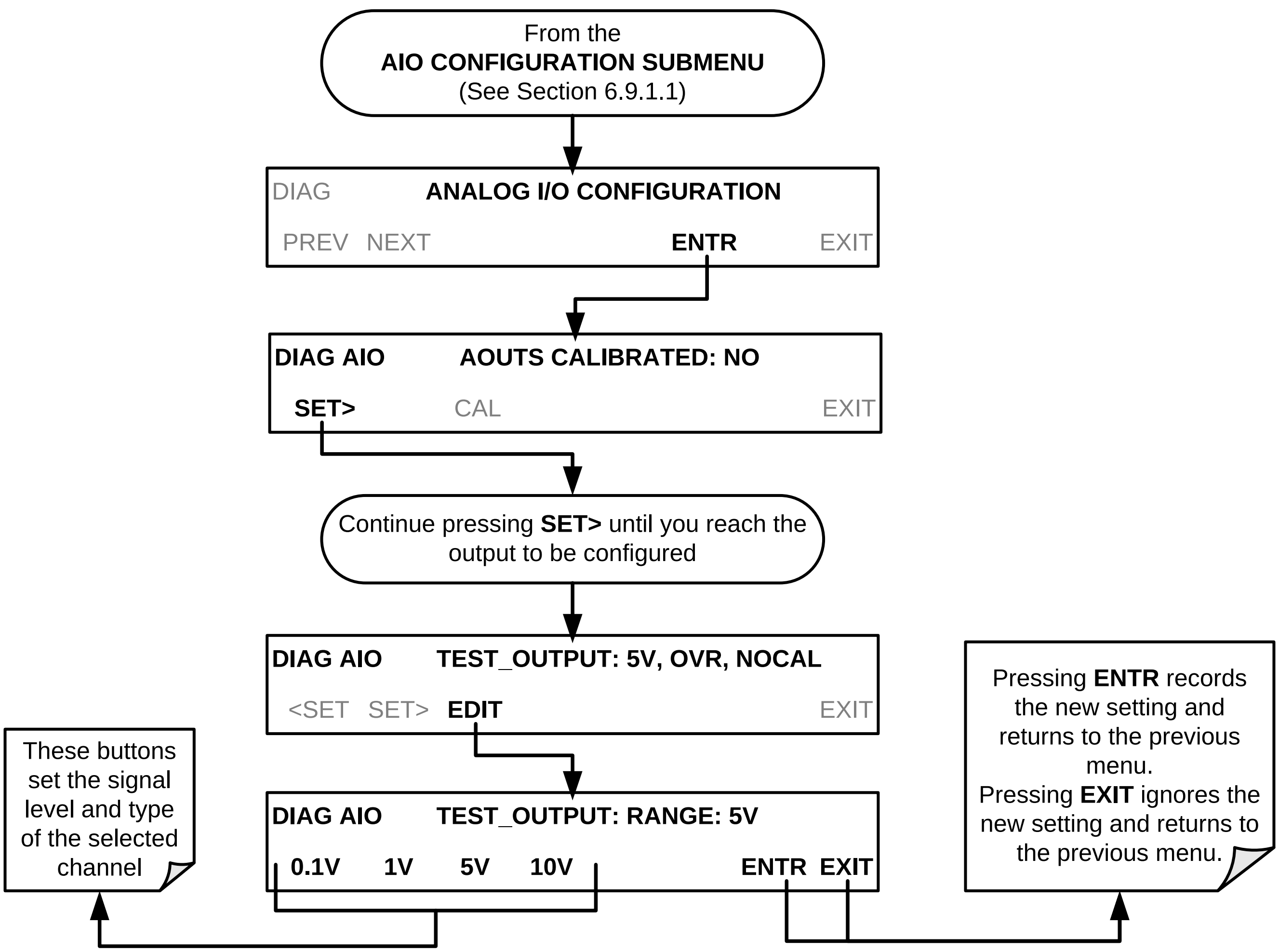
6.9.1.3. TEST CHANNEL VOLTAGE RANGE Configuration

In its standard configuration, the analog outputs is set to output a 0 – 5 VDC signals. Several other output ranges are available (see Table 6-14). Each range is usable from -5% to + 5% of the rated span.

Table 6-14: 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.		

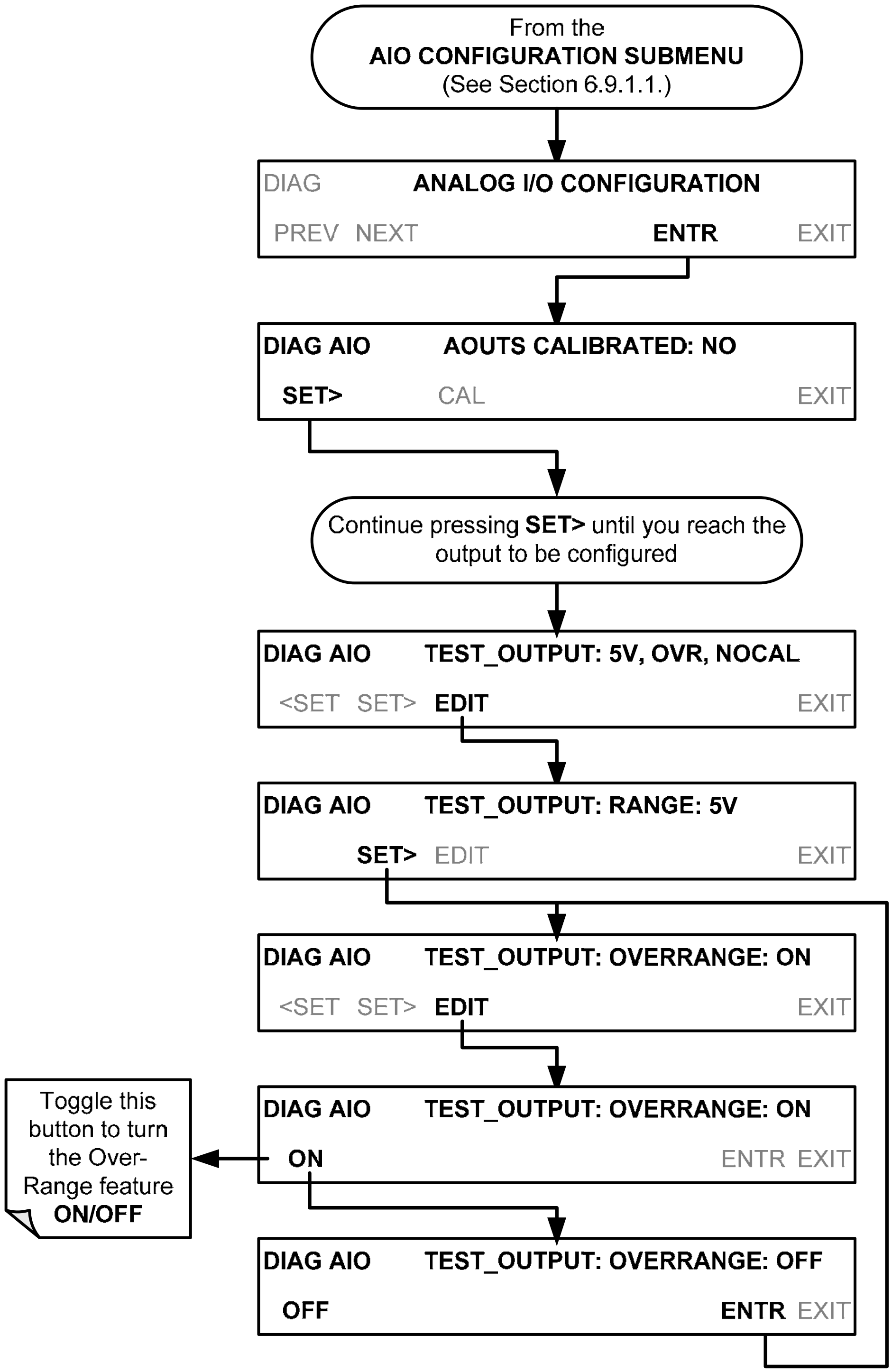
To change the output range, press:



6.9.1.4. Turning the TEST CHANNEL Over-Range Feature ON/OFF

In its default configuration, a ± 5% over-range is available on each of the T700's **TEST CHANNEL** output. This over-range can be disabled if your recording device is sensitive to excess voltage or current.

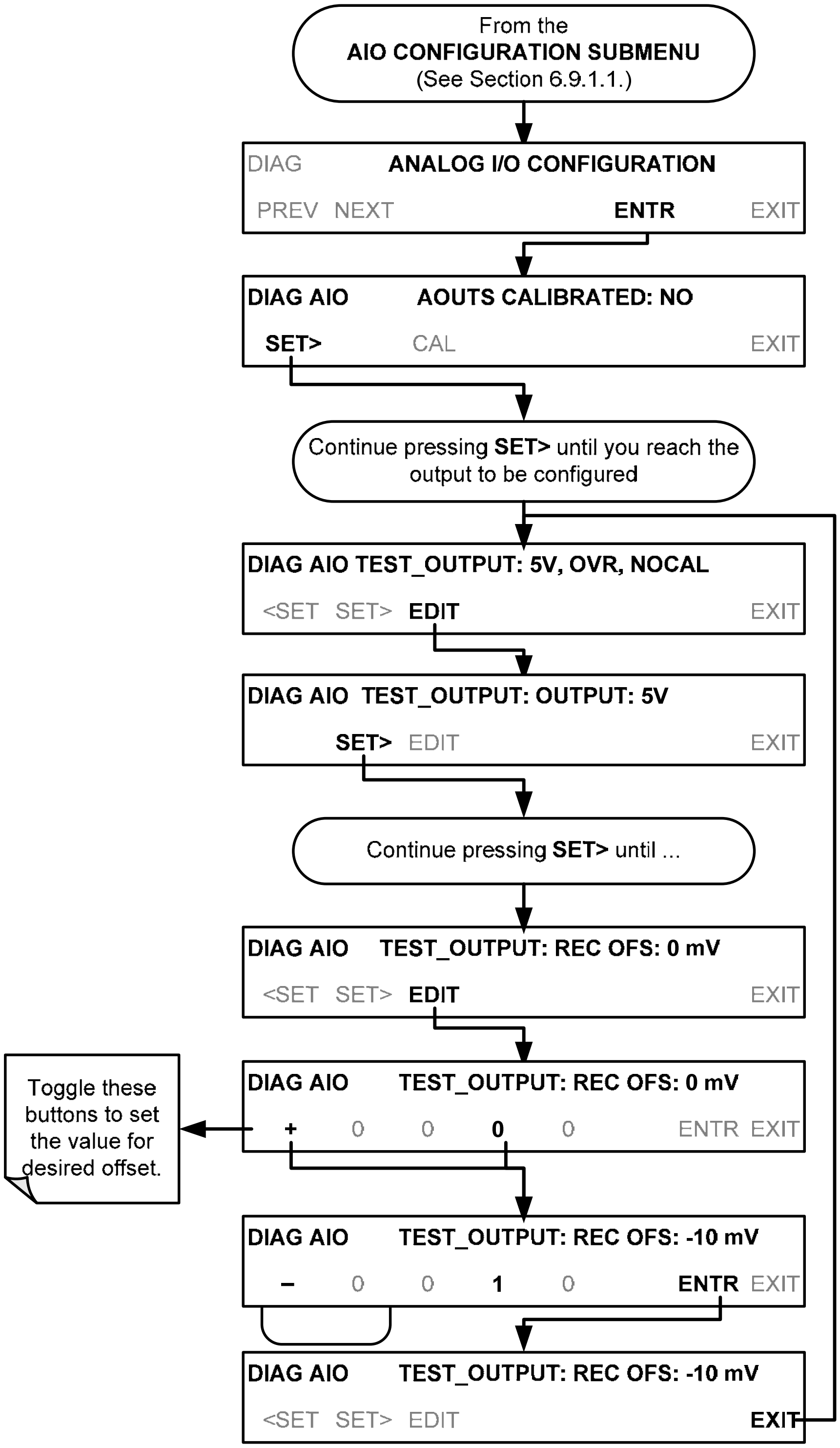
To turn the over-range feature on or off, press:



6.9.1.5. 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 T700 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:



6.9.2. TEST CHANNEL CALIBRATION

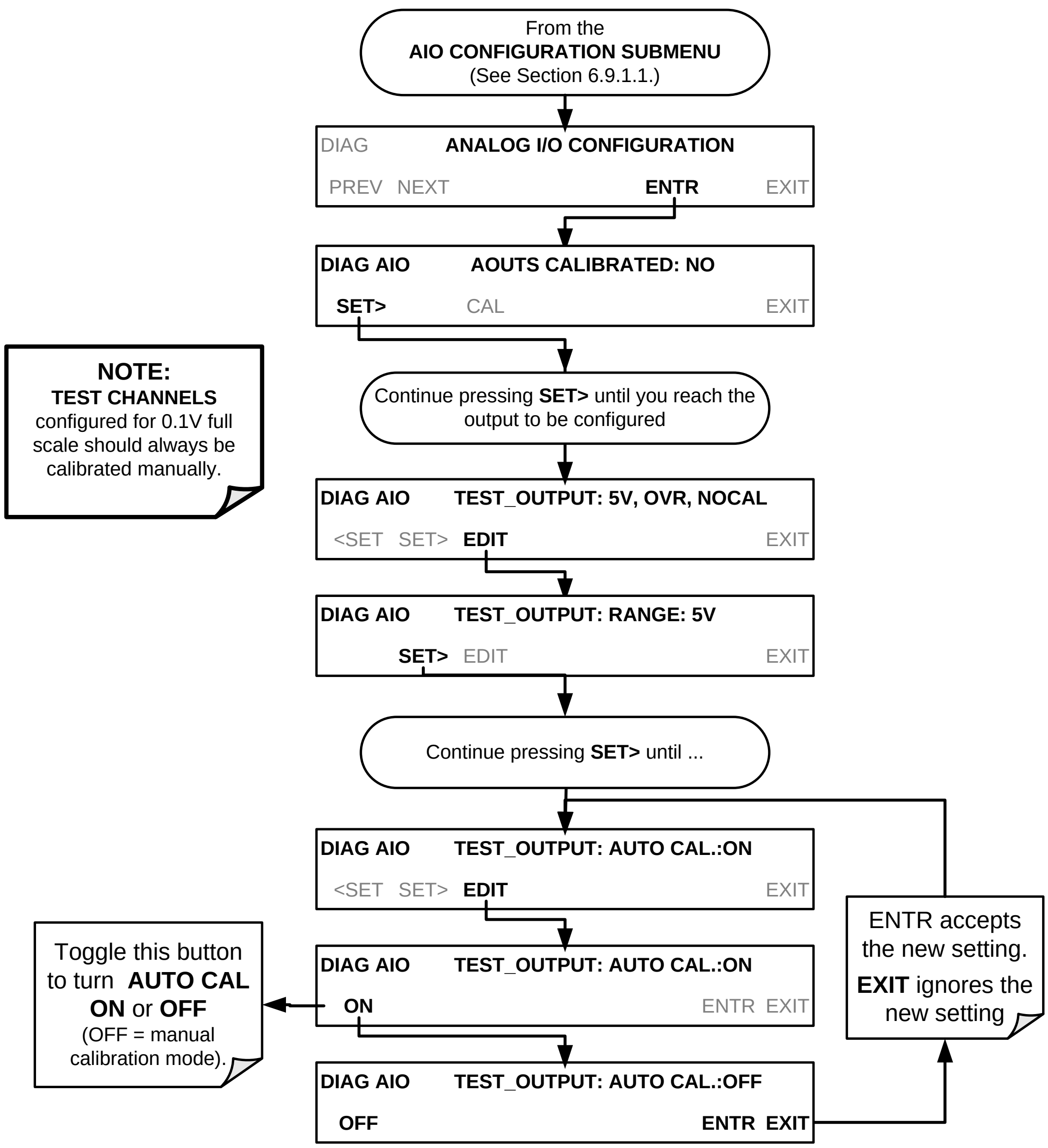
TEST CHANNEL calibration needs to be carried out on first startup of the calibrator (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically or adjusted manually.

During automatic calibration, the calibrator tells the output circuitry to generate a zero mV signal and high-scale point signal (usually about 90% of chosen analog signal scale) then measures actual signal of the output. Any error at zero or high-scale is corrected with a slope and offset.

Automatic calibration can be performed via the **AOUTS CALIBRATION** command, or by using the **CAL** button located inside **TEST_CHANNEL** submenu. By default, the calibrator is configured so that calibration of **TEST CHANNEL** can be initiated with the **AOUTS CALIBRATION** command.

6.9.2.1. Enabling or disabling the TEST CHANNEL Auto-Cal Feature

To enable or disable the Auto-Cal feature for the **TEST CHANNEL**, press:



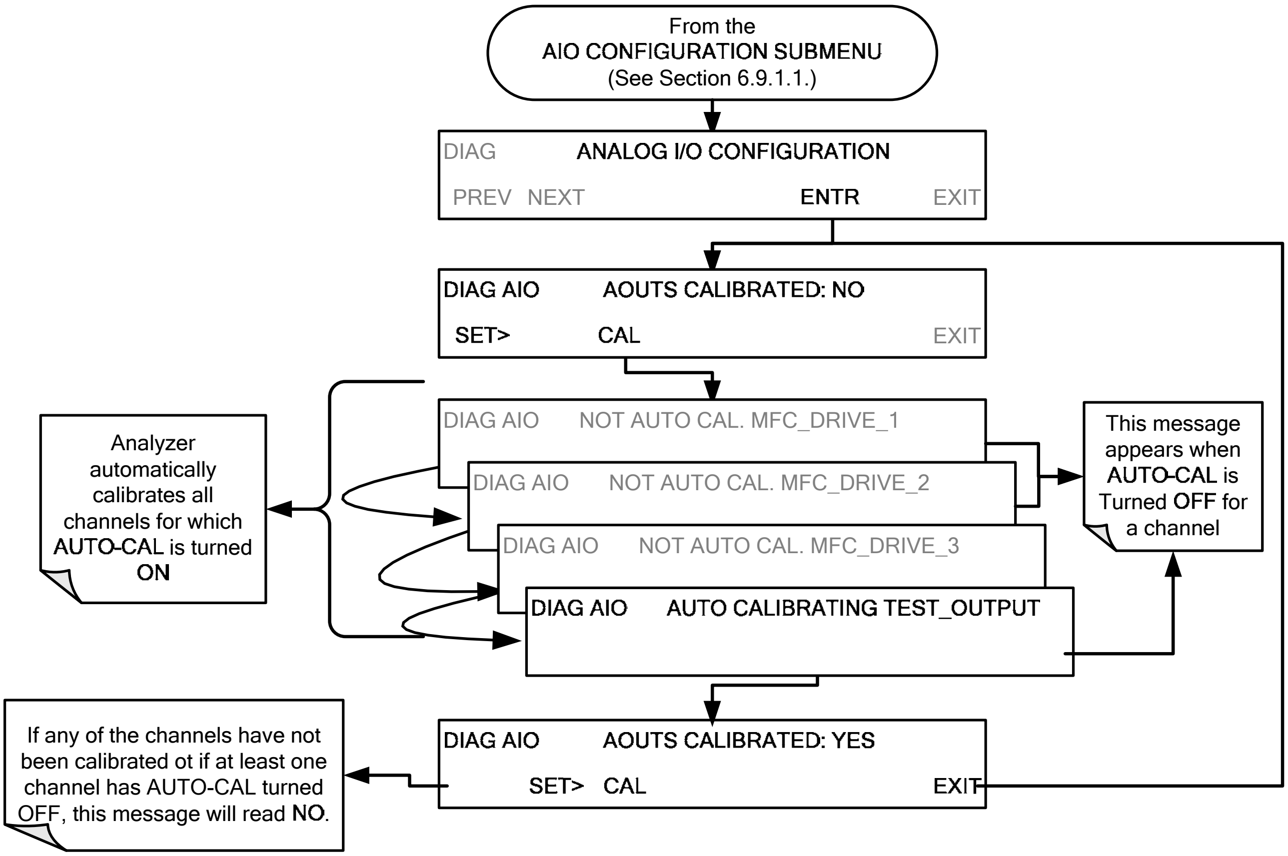
6.9.2.2. Automatic TEST CHANNEL Calibration

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 9 if installed)

Ensure that the AUTO CAL feature is turned ON for the TEST CHANNEL (See Section 6.9.2.1)

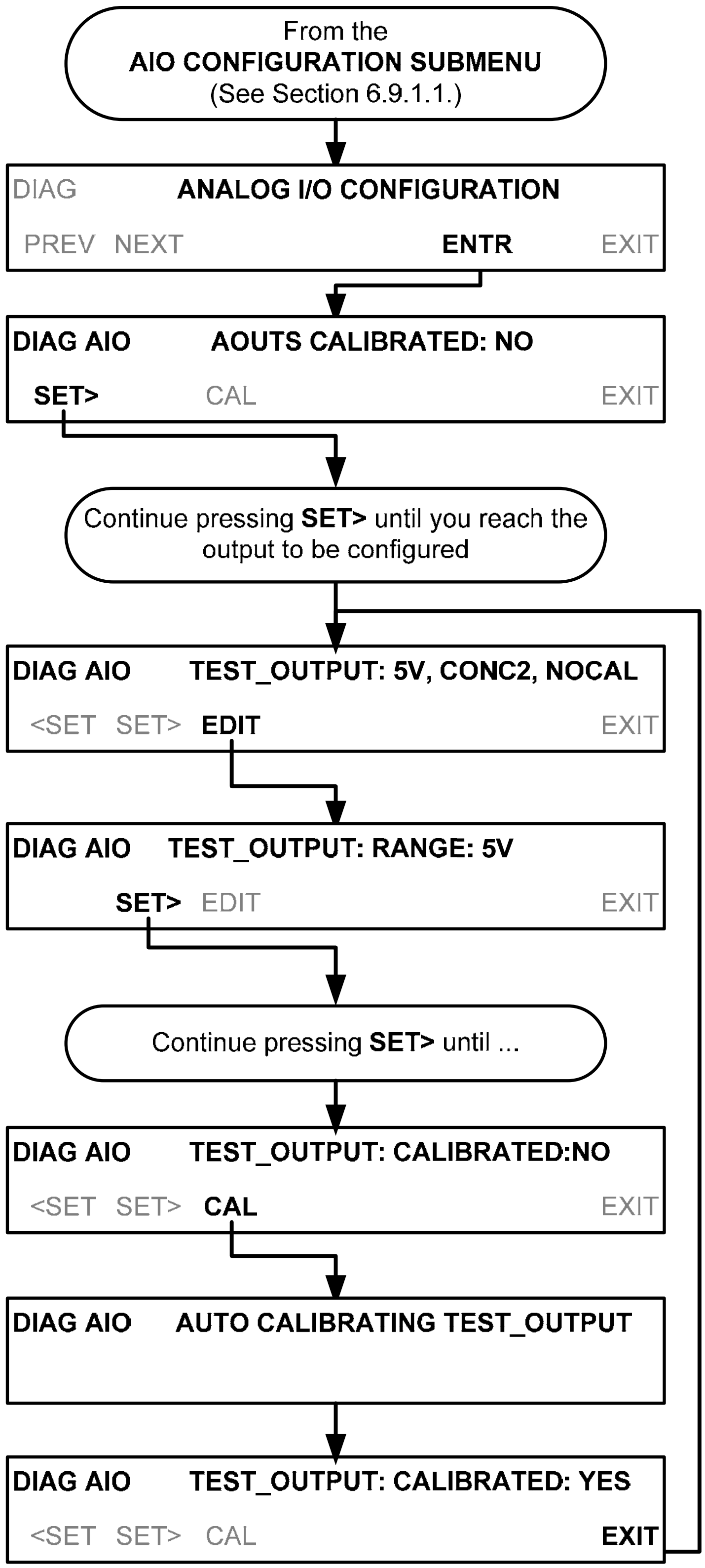
To calibrate the outputs as a group with the **AOUTS CALIBRATION** command, press:



NOTE

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

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



6.9.2.3. 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 6.9.2.1).

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

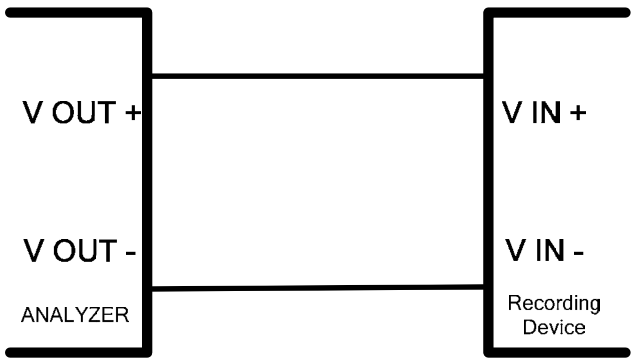
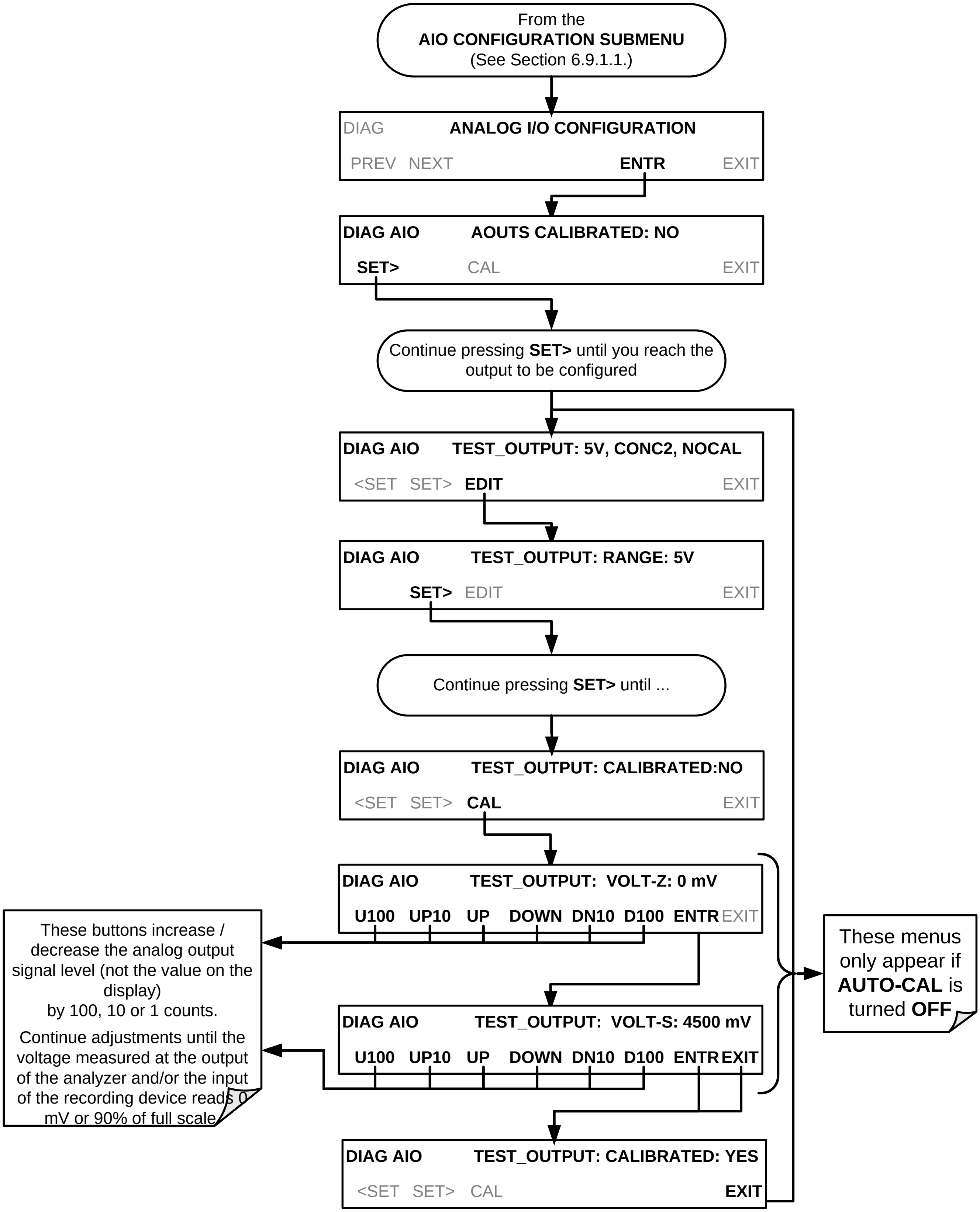


Figure 6-11: Setup for Calibrating the TEST CHANNEL

Table 6-15: 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

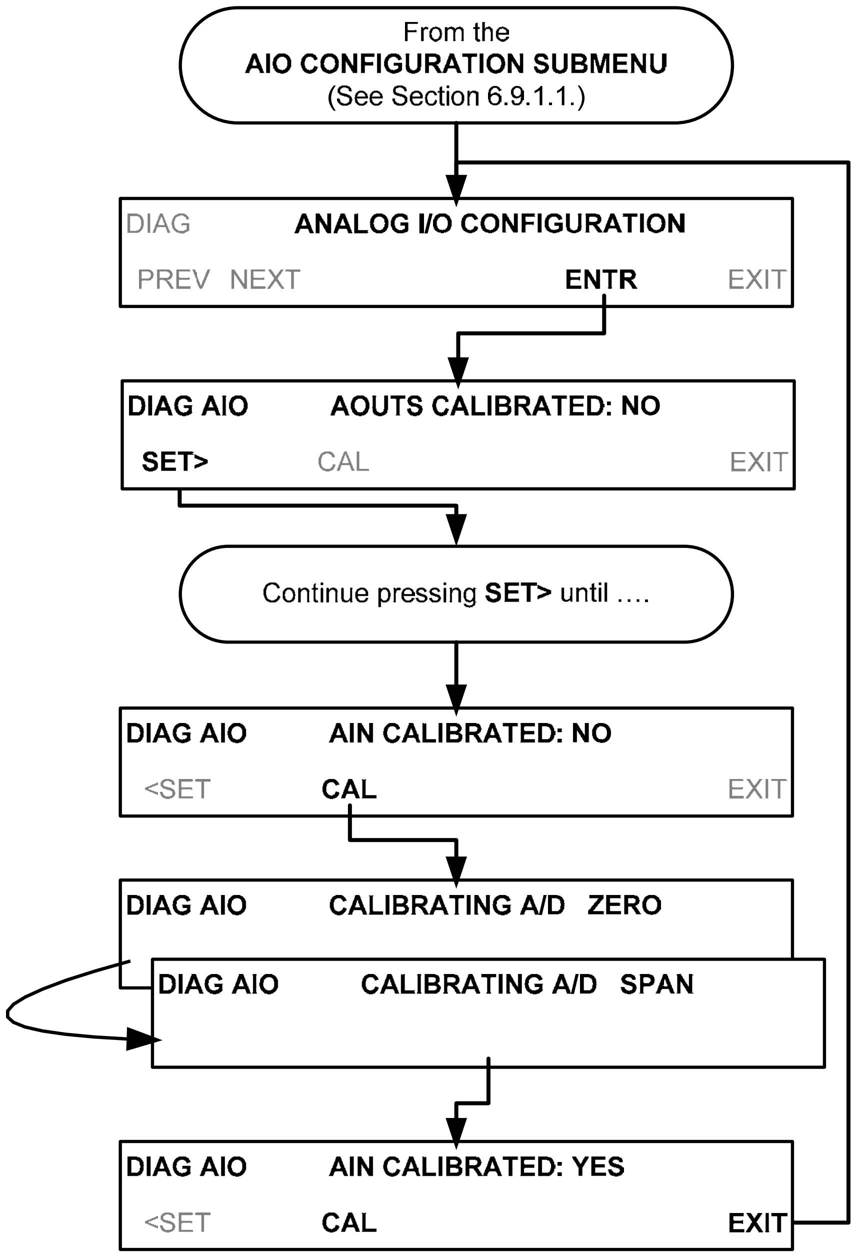
To adjust the signal levels of an analog output channel manually, press:



6.9.3. AIN CALIBRATION

This is the sub-menu calibrates the calibrator's A-to-D conversion circuitry. This calibration is only necessary after amajor repair such as the replacement of a CPU, a motherboard or a power supply.

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



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

The T700 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 T700 variables that are accessible through the remote interface.

Table 6-16: 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
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 3.3.9).	ON/OFF	OFF
4	**UNASSIGNED**			
5	*STD_TEMP*[1]	*Sets the standard Temperature used in calculating O_3 flow rates and concentrations.*	*0ºC and 100ºC*	*25ºC*
6	*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*
7	**CLOCK_ADJ**	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast (See Section 6.7).	-60 to +60 s/day Default=0	0

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

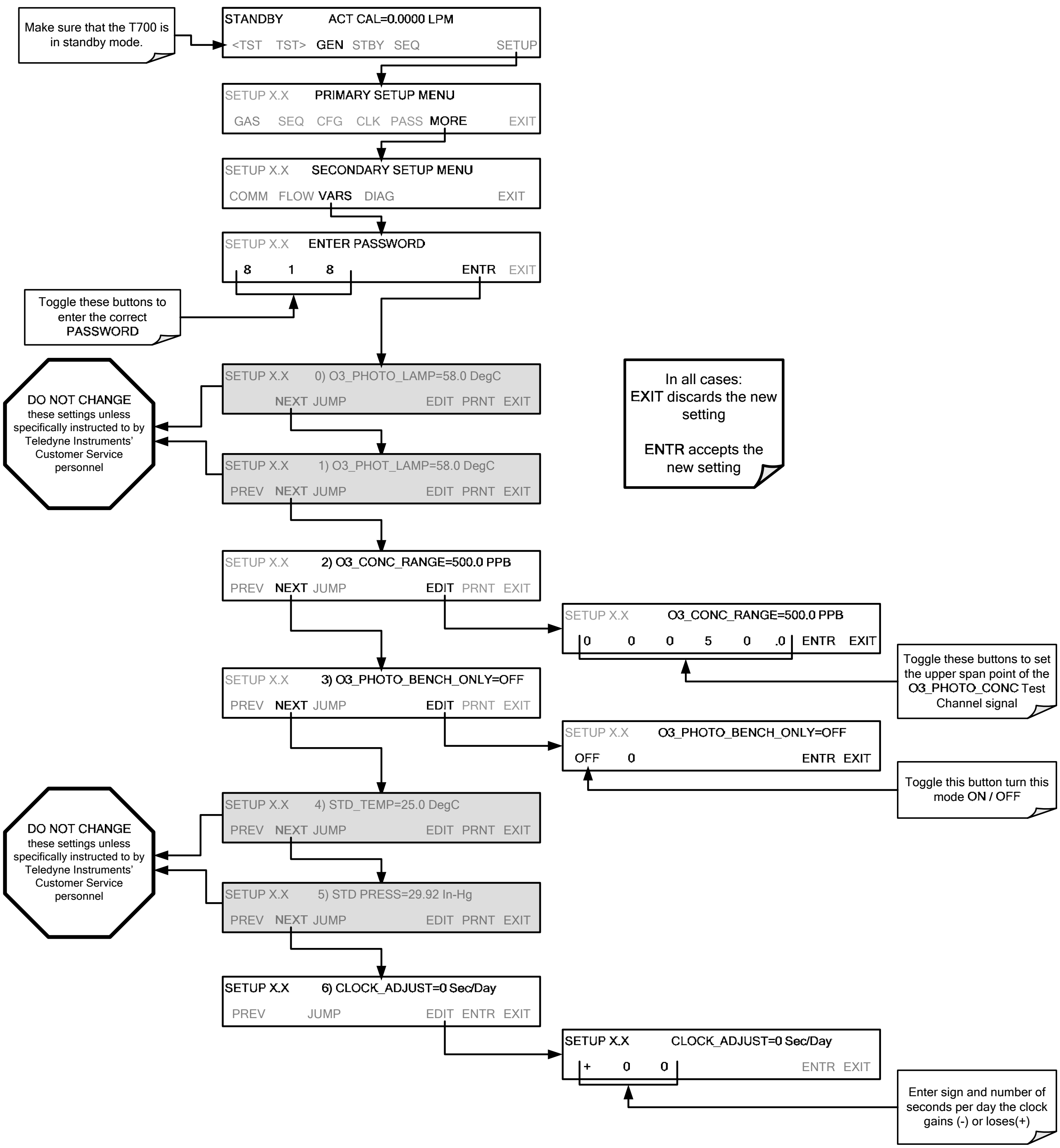
[2] Only available in calibrators with O_3 photometer and generator options installed.

NOTE

There is a 2-second latency period between when a VARS value is changed and the new value is stored into the analyzer's memory.

DO NOT turn the analyzer off during this period or the new setting will be lost.

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



6.11. SETUP → LVL: SETTING UP AND USING LEADS (DASIBI) OPERATING LEVELS

6.11.1. GENERAL INFORMATION ABOUT LEADS LEVELS

The T700 calibrator can be equipped with a version of firmware that includes support for LEADS, a data collection and analysis system LEADS specifically designed for handling meteorological and environmental data particularly when there is a need to integrate data and control instrumentation from several different manufacturers. When an T700 calibrator is equipped with the optional LEADS software used in conjunction with dataloggers located in the central data analysis facility it is possible to collect and buffer data between the various calibrators, analyzers and metrological equipment remotely located at an air monitoring station.

Because LEADS was originally developed for use with TNRCC using Dasibi 5008 calibrators, the LEADS version of the T700 includes support for Dasibi "Dot" serial data commands and operational "LEVEL's".

It also includes a method for driving external devices via contact closure control outputs in conjunction with an optional bolt-on valve driver assembly (see Section 5.8).

NOTE

For more information on the LEADS system, please go to http://www.meteostar.com/.

6.11.2. DOT COMMANDS

The Dasibi "Dot" commands form a text-based (ASCII) data protocol that is transmitted between a control computer (XENO data logger in this case) and a calibrator or ambient gas analyzer over an RS-232 connection. The details of the protocol are beyond the scope of this document, but in its simplest form the protocol is based on a two or three digit integer preceded by a control-A and a period (.) and then followed by a "!" and a two digit checksum.

EXAMPLE:

^A.xxx!nn

For further information on dot commands, please contact Teledyne API'S Customer Service.

A T700 equipped with LEADS software can be simultaneously operated over the same COMM port using standard Teledyne API's serial data commands and is compatible with APICOM versions 5 and later which include an added feature that allows a user to edit, upload and download level tables.

6.11.3. LEVELS

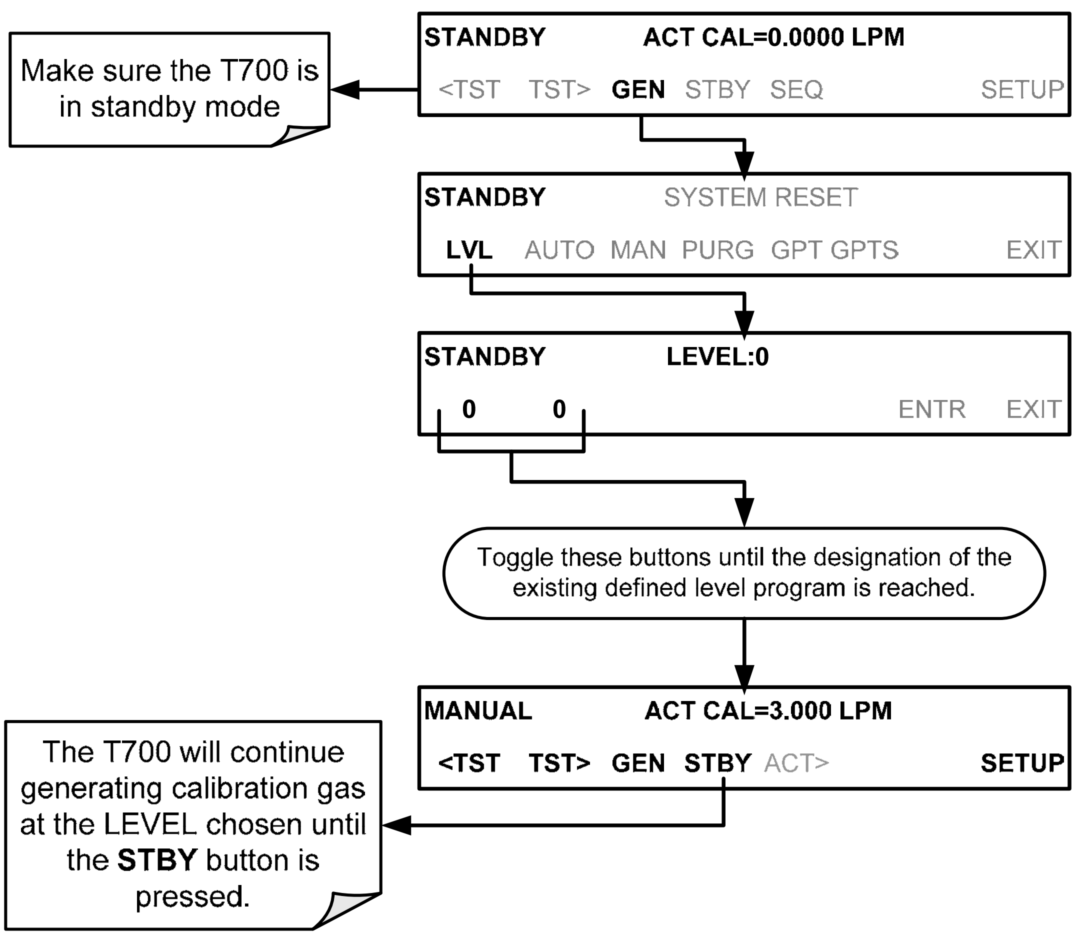
A **LEVEL** is a combination of several parameters:

- An ID number for the LEVEL
- An action, (e.g. GENERATE, GPT, GPTPS & MANUAL)
  - A target concentration value
  - An output flow rate (if applicable)
  - Configuration for one or both of two status output blocks.

Up to twenty levels can be defined and used with the T700 using a range of ID numbers from 0-98. Level 99 is reserved for standby. The levels are not time based and do not include characteristics such as start time or duration, therefore a single LEVEL can not switch between different concentration levels and flow rates. Separate flow and concentration outputs must be programmed into separate LEVELs which are then individually started and stopped either by an operator at the calibrator's front panel or through a serial data operation over the RS-232 or Ethernet ports.

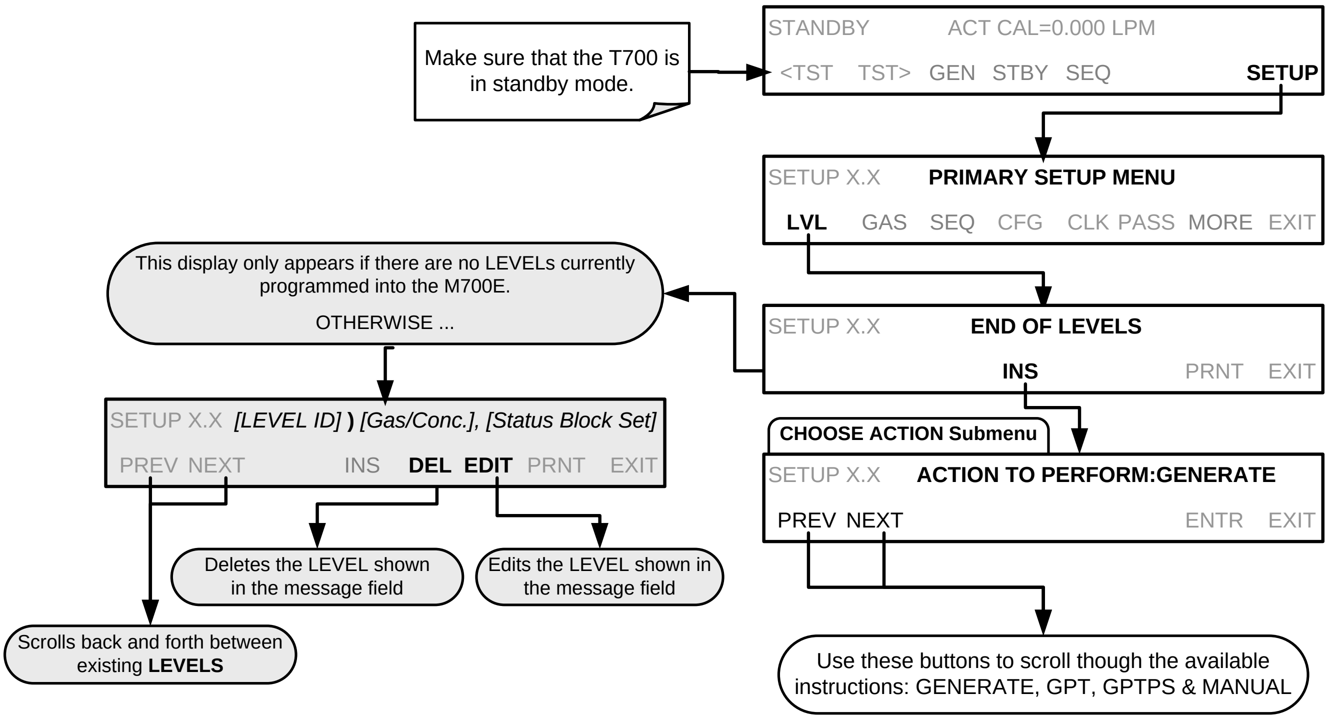
6.11.4. ACTIVATING AN EXISTING LEVEL

To activate an existing defined **LEVEL**, press:



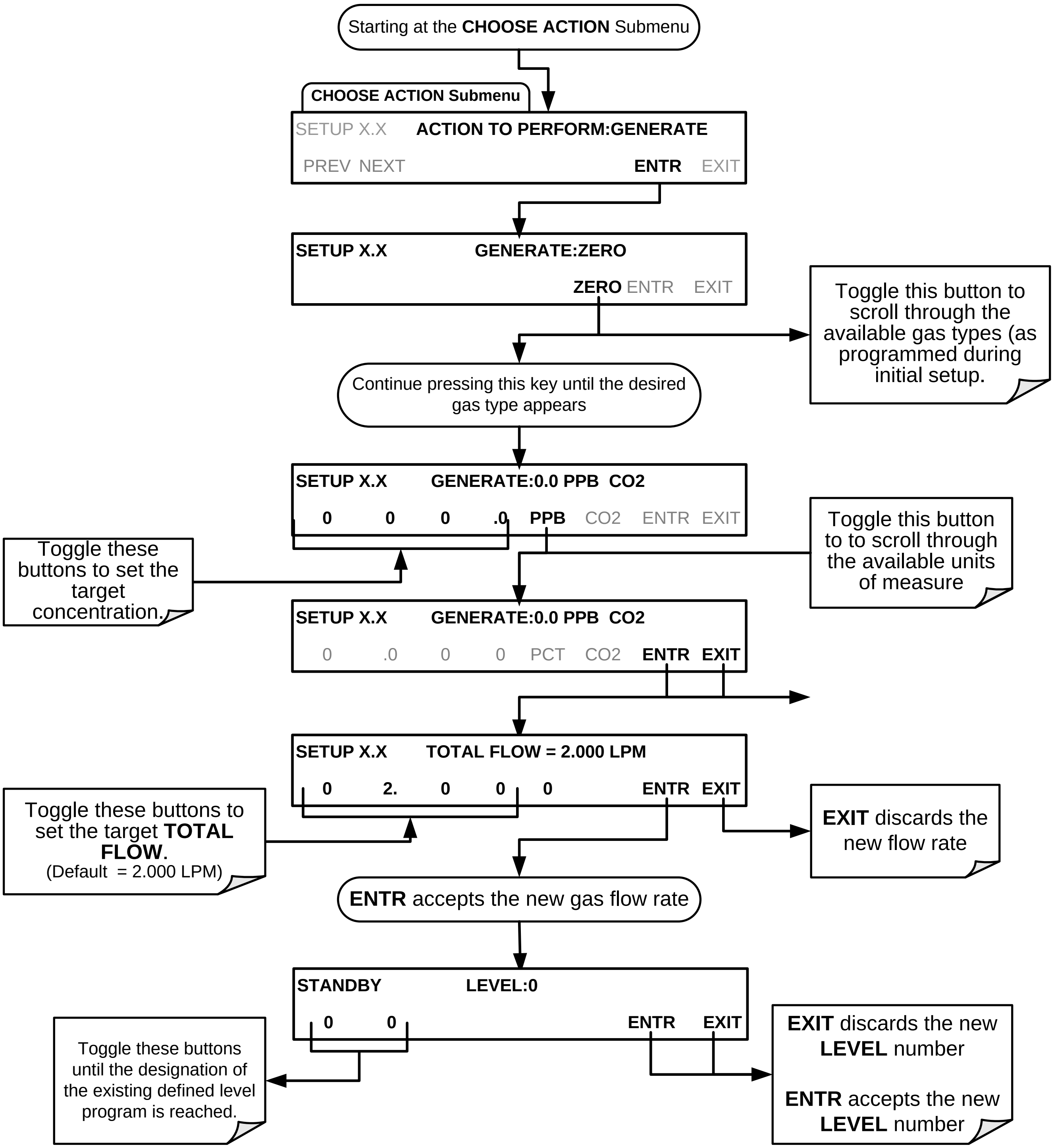
6.11.5. PROGRAMMING NEW LEVELS

To begin programming a new **LEVEL** find the **LVL** submenu by pressing:



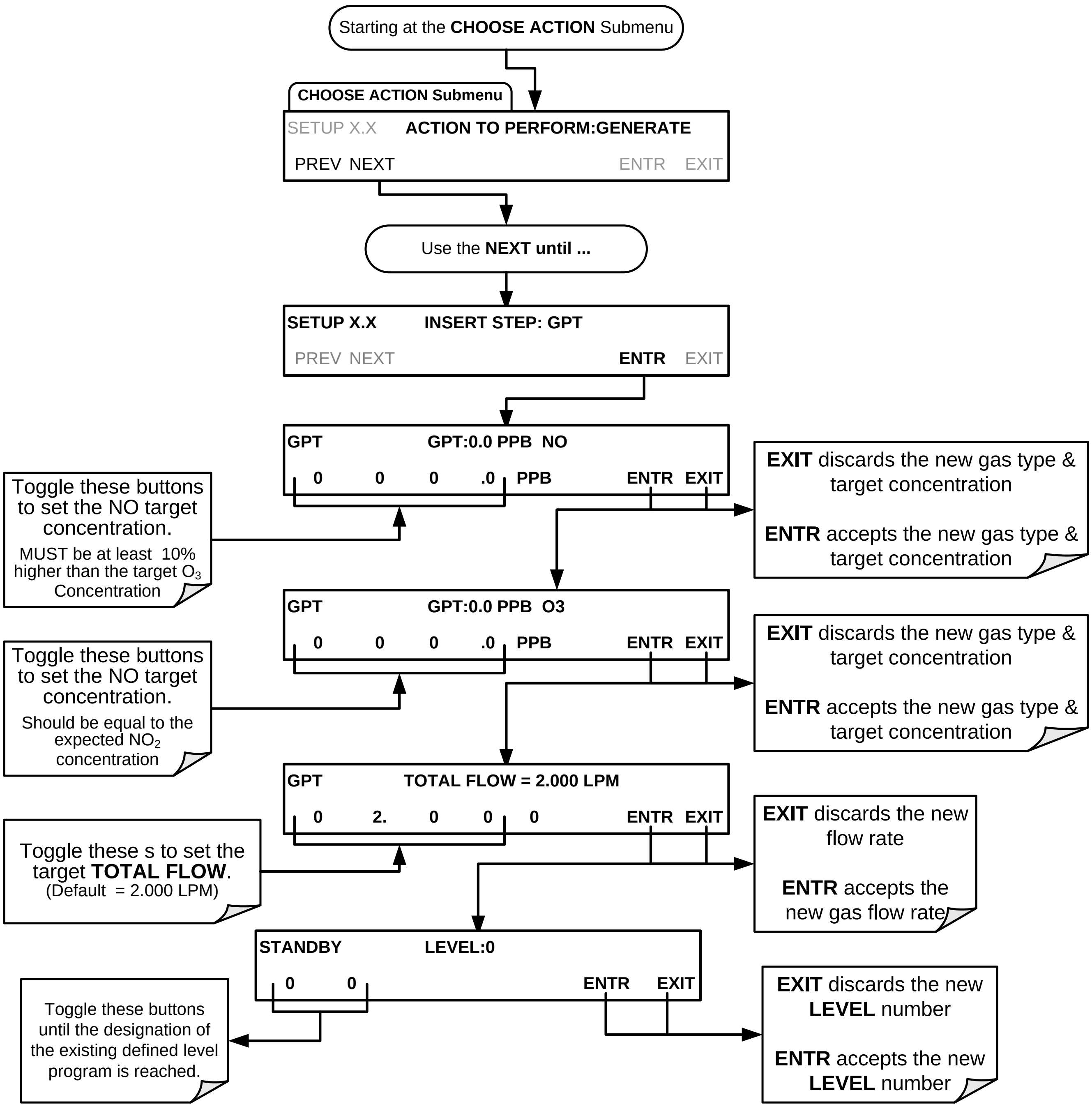
6.11.5.1. Creating a GENERATE LEVEL

To create a **LEVEL** using the T700's **AUTO** generation function, press:



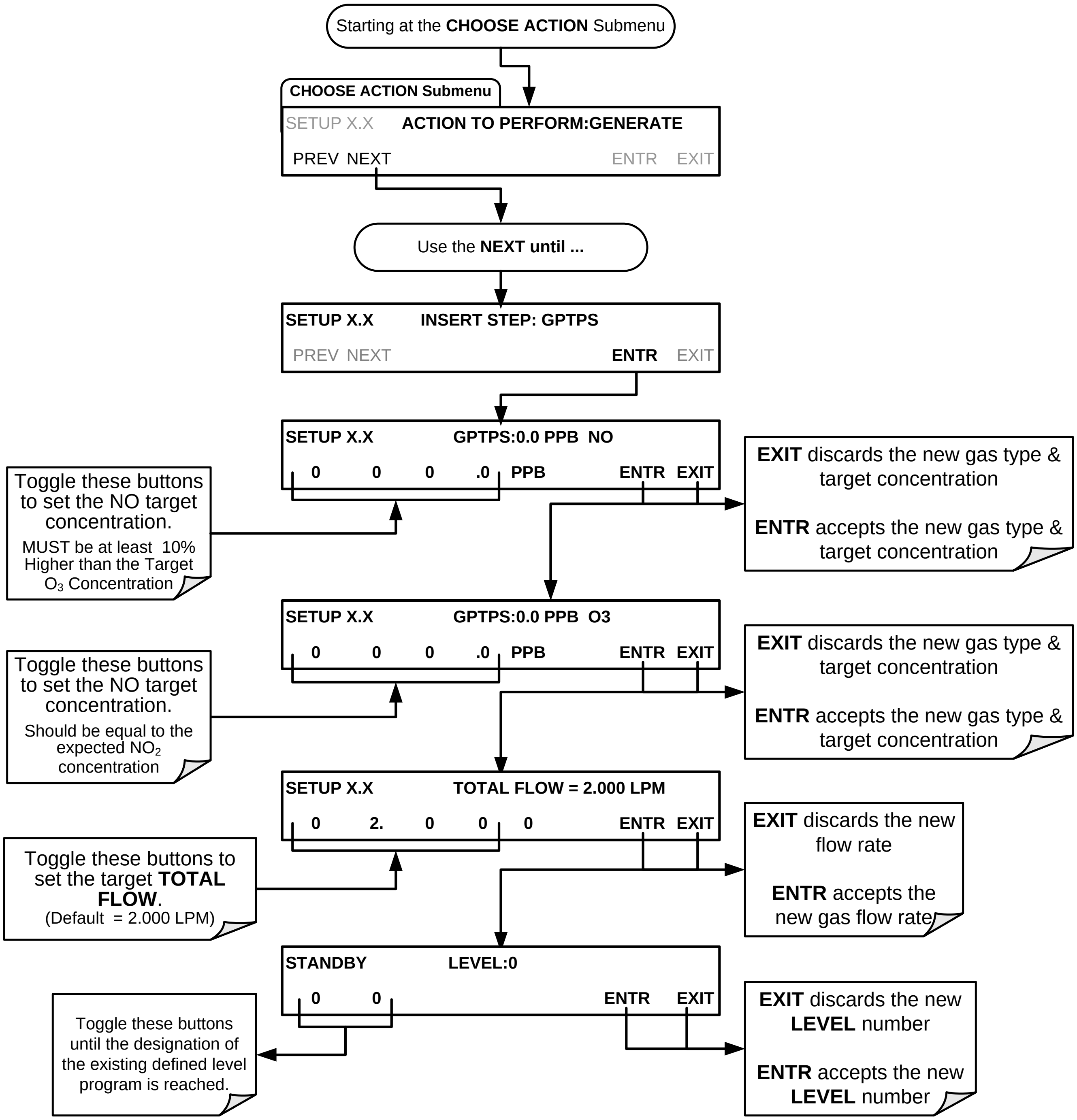
6.11.5.2. Creating a GPT LEVEL

To create a **LEVEL** using the T700's **GPT** function, press:



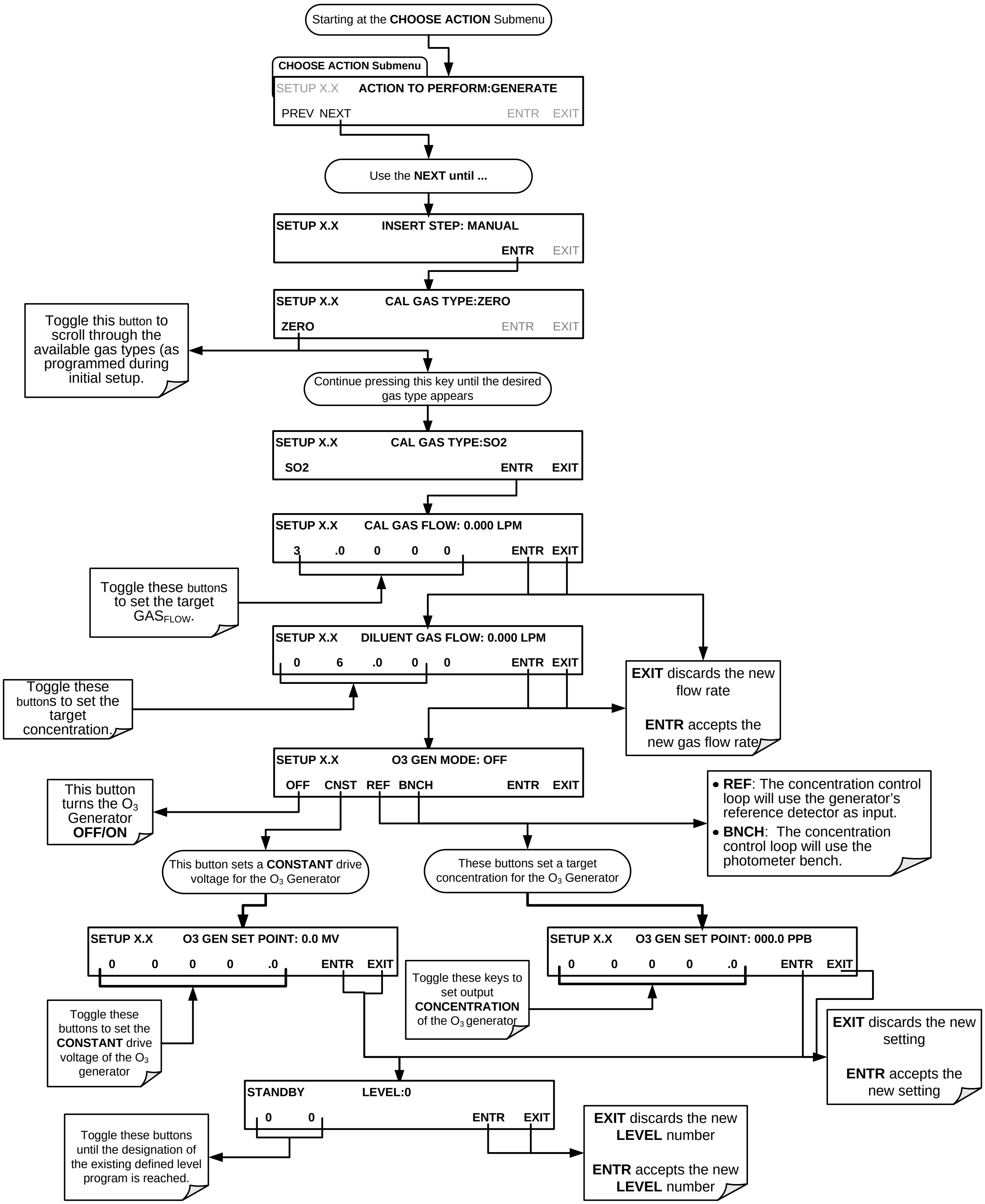
6.11.5.3. Creating a GPTPS LEVEL

To create a **LEVEL** using the T700's **GPTPS** function, press:



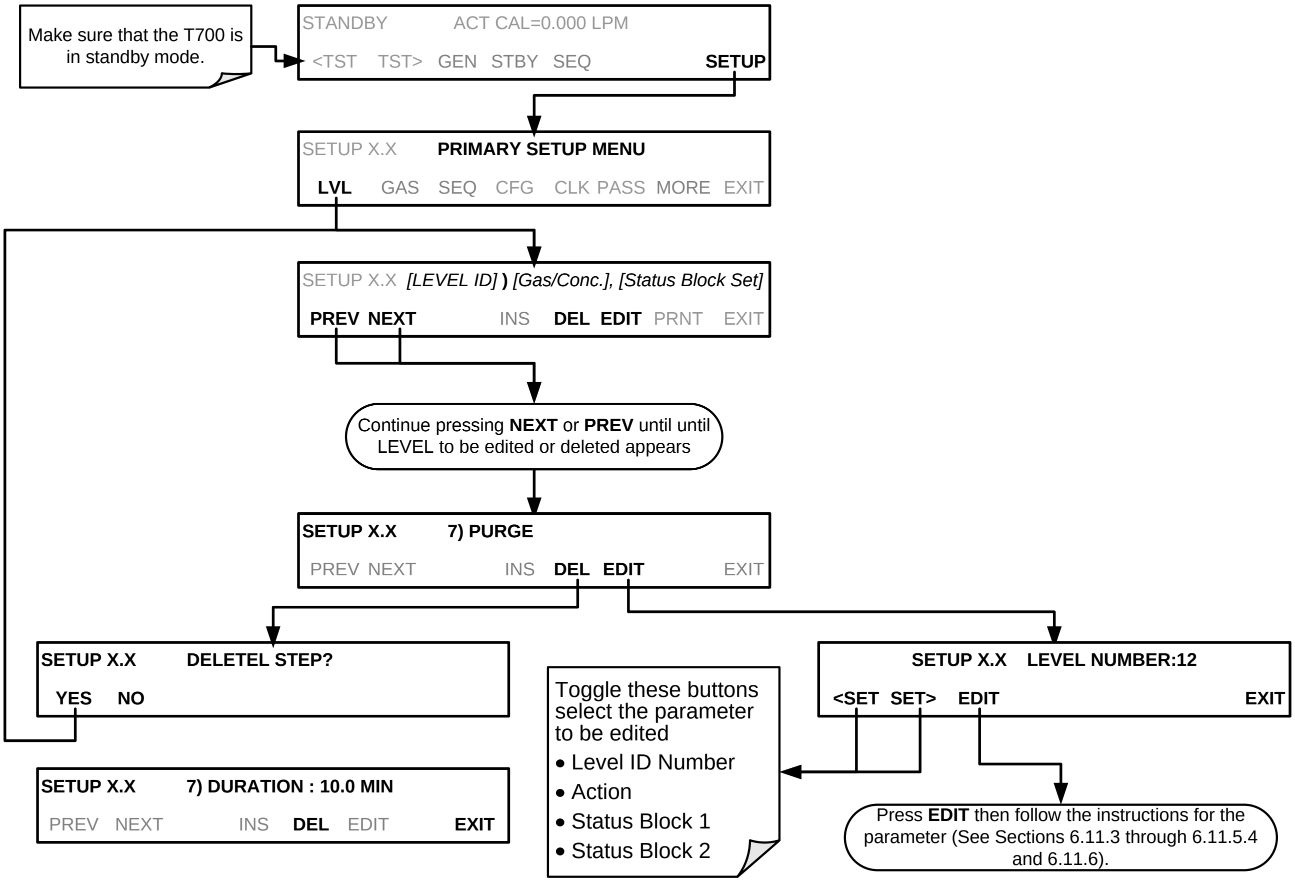
6.11.5.4. Creating a MANUAL LEVEL

To create a level using the T700's **MANUAL** generation function, press:



6.11.5.5. Editing or Deleting a LEVEL

To edit or delete an existing **LEVEL**, press:

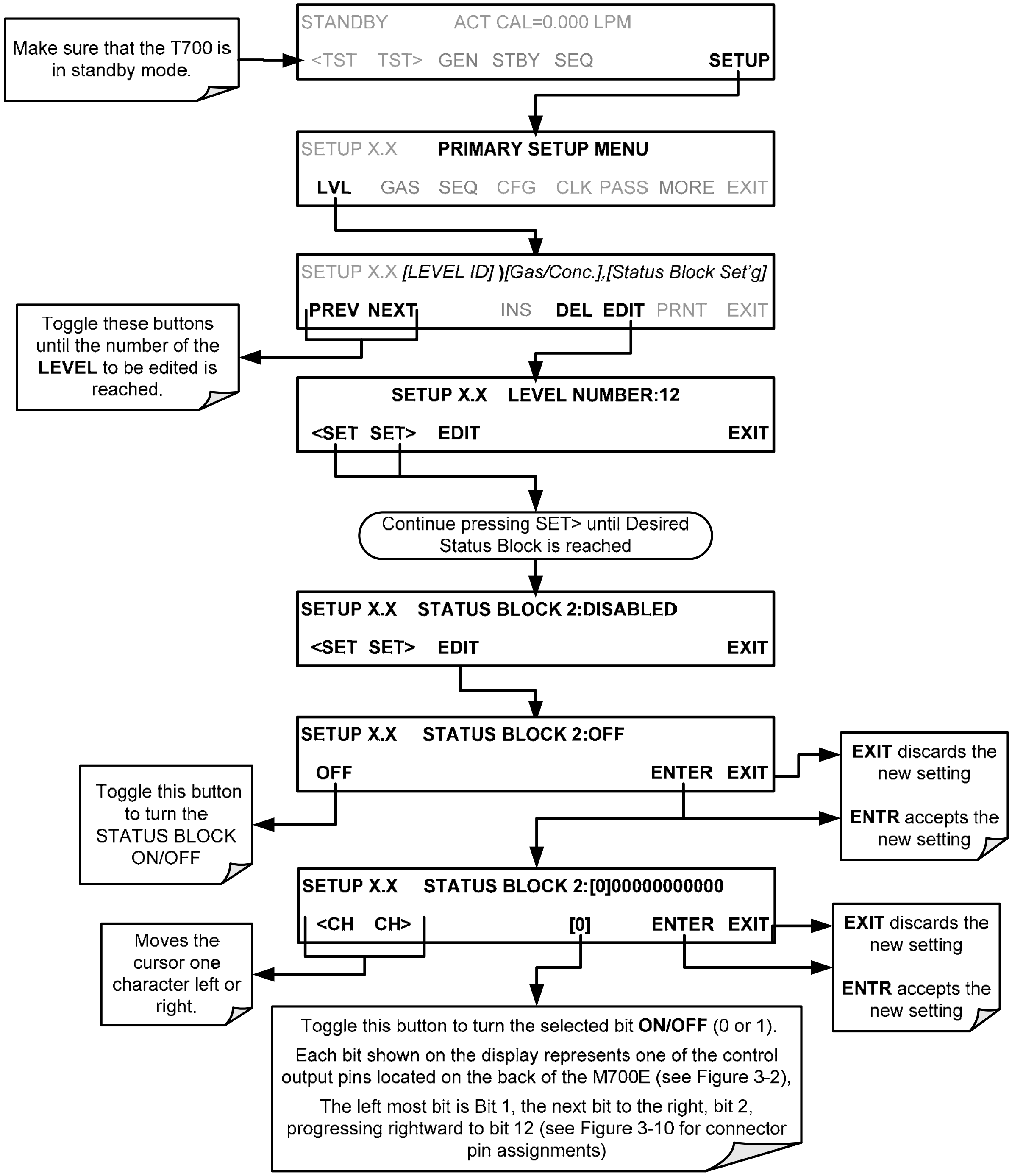


6.11.6. CONFIGURING LEVEL STATUS BLOCKS

There are two **STATUS BLOCKS** associated with **LEADS LEVELS**.

- **BLOCK 1:** This block corresponds to the physical CONTROL OUTPUT connections located on the back panel of the T700 (see Figure 3-4 and Section 3.1.2.5).
- **BLOCK 2**: The second status block does not correspond to any physical output but is used to communicate status over the serial data port.

To configure the either of the **STATUS BLOCKS**, press:



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7. REMOTE OPERATION

This section presents several methods for remote operation.

7.1. USING THE ANALYZER'S COMMUNICATION PORTS

The T700 is equipped with two serial communication ports (RS232 and COM2), a USB port and an Ethernet port located on the rear panel. The two serial ports are accessible via two DB-9 connectors (see Figure 3-4): 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; See Section 5.6.2 and 7.2.1).
- The COM2 port can be configured for standard RS-232 operation, half-duplex RS-485 communication. (See Section 7.4).

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 7.4). 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 7.4.1.1). 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 direct communication between the calibrator and a PC or laptop computer.

7.1.1. RS-232 DTE AND DCE COMMUNICATION

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic data terminals always fall into the DTE category whereas modems are always considered DCE devices.

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.

A switch located below the serial ports on the rear panel allows the user to switch between DTE (for use with data terminals) or DCE (for use with modems). Since computers can be either DTE or DCE, check your computer to determine which mode to use.

7.1.2. COMM PORT DEFAULT SETTINGS AND CONNECTOR PIN ASSIGNMENTS

Received from the factory, the calibrator is set up to emulate an RS-232 DCE device.

- **RS-232 (COM1)**: RS-232 (fixed), DB-9 male connector.
  - **Baud rate**: 19200 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**: 115000 bits per second (baud).
  - **Data Bits**: 8 data bits with 1 stop bit.
  - **Parity**: None.

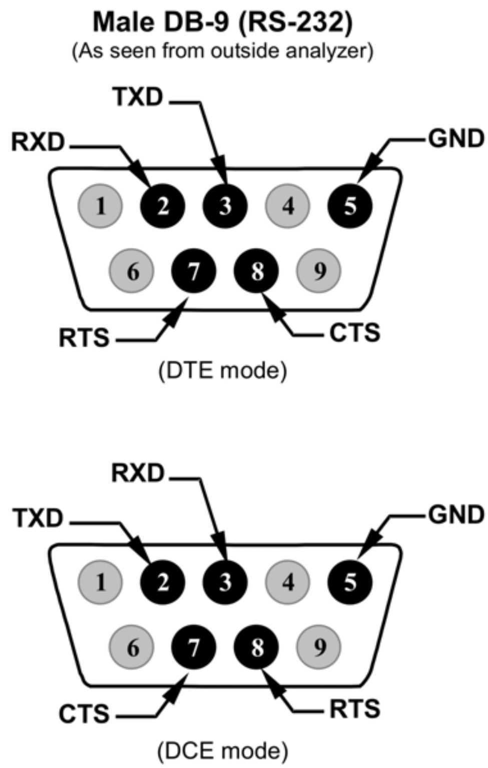


Figure 7-1: Default Pin Assignments for Back Panel COMM Port Connectors (RS-232 DCE & DTE)

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 7-2.

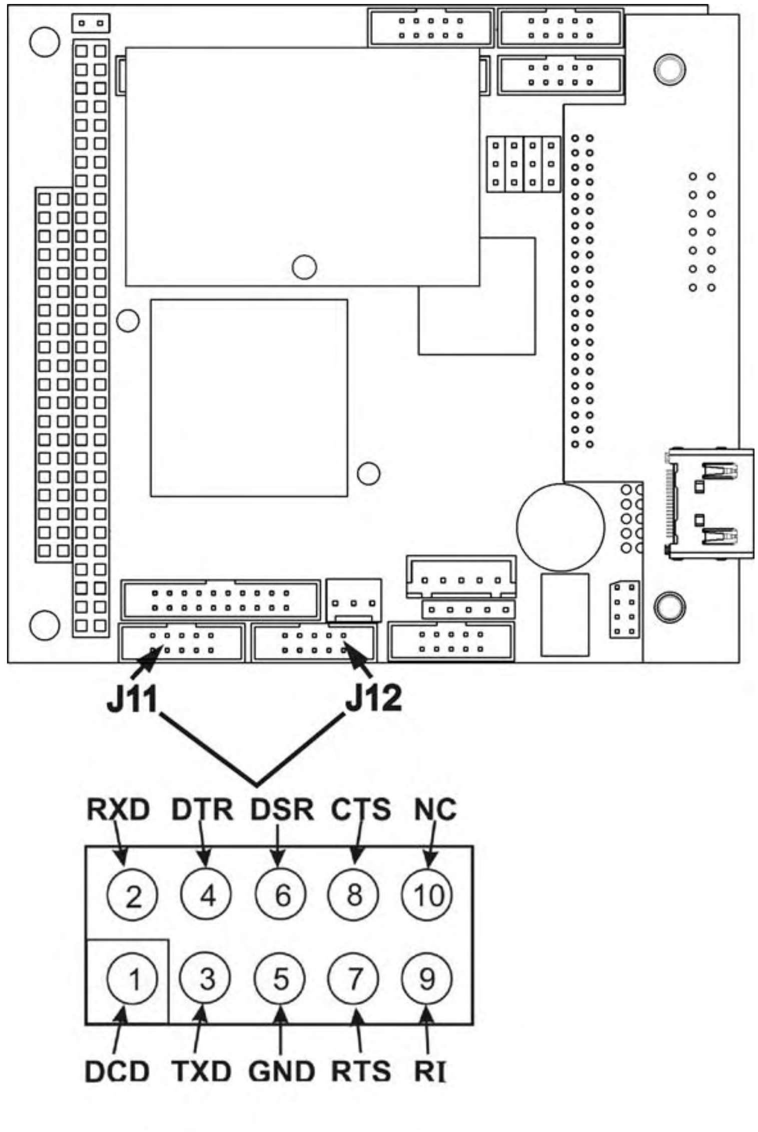


Figure 7-2: Default Pin Assignments for CPU COMM Port Connector (RS-232).

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. Also available as Option 60B (see Section 5.6.1).
- 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. Also available as Option 60A (see Section 5.6.1).

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.

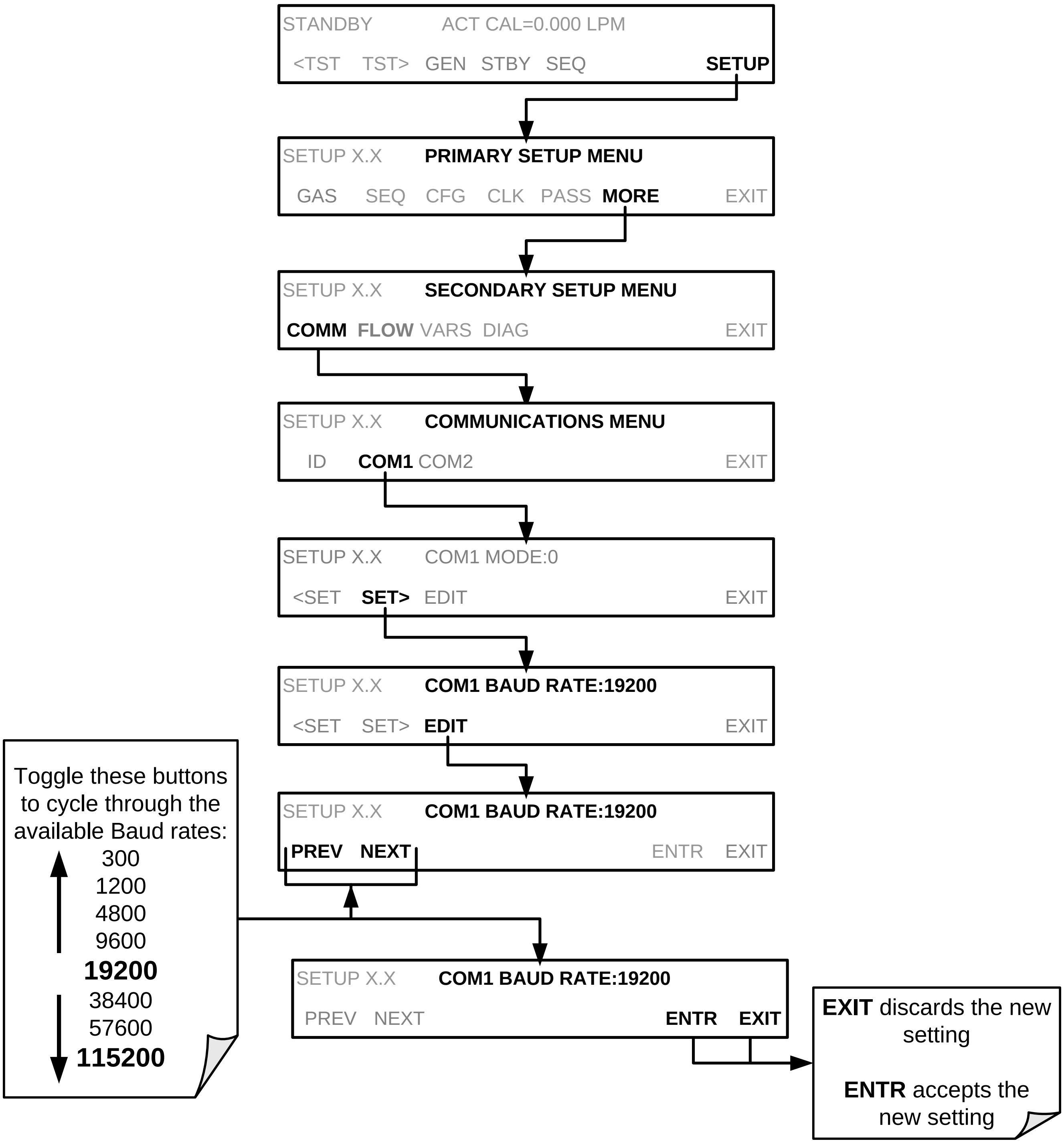
To assist in properly connecting the serial ports to either a computer or a modem, there are activity indicators just above the RS-232 port. Once a cable is connected between the calibrator and a computer or modem, both the red and green LEDs should be on.

If the lights are not lit, use small switch on the rear panel to switch it between DTE and DCE modes.

If both LEDs are still not illuminated, ensure the cable properly connected.

7.1.3. COMM PORT BAUD RATE

To select the baud rate of either one of the COMM Ports, press:



7.1.4. COMM PORT COMMUNICATION MODES

Each of the calibrator's serial ports can be configured to operate in a number of different modes, listed in Table 7-1. As modes are selected, the calibrator sums the Mode ID numbers and displays this combined number on the front panel display. 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 7-1: COMM Port Communication Modes

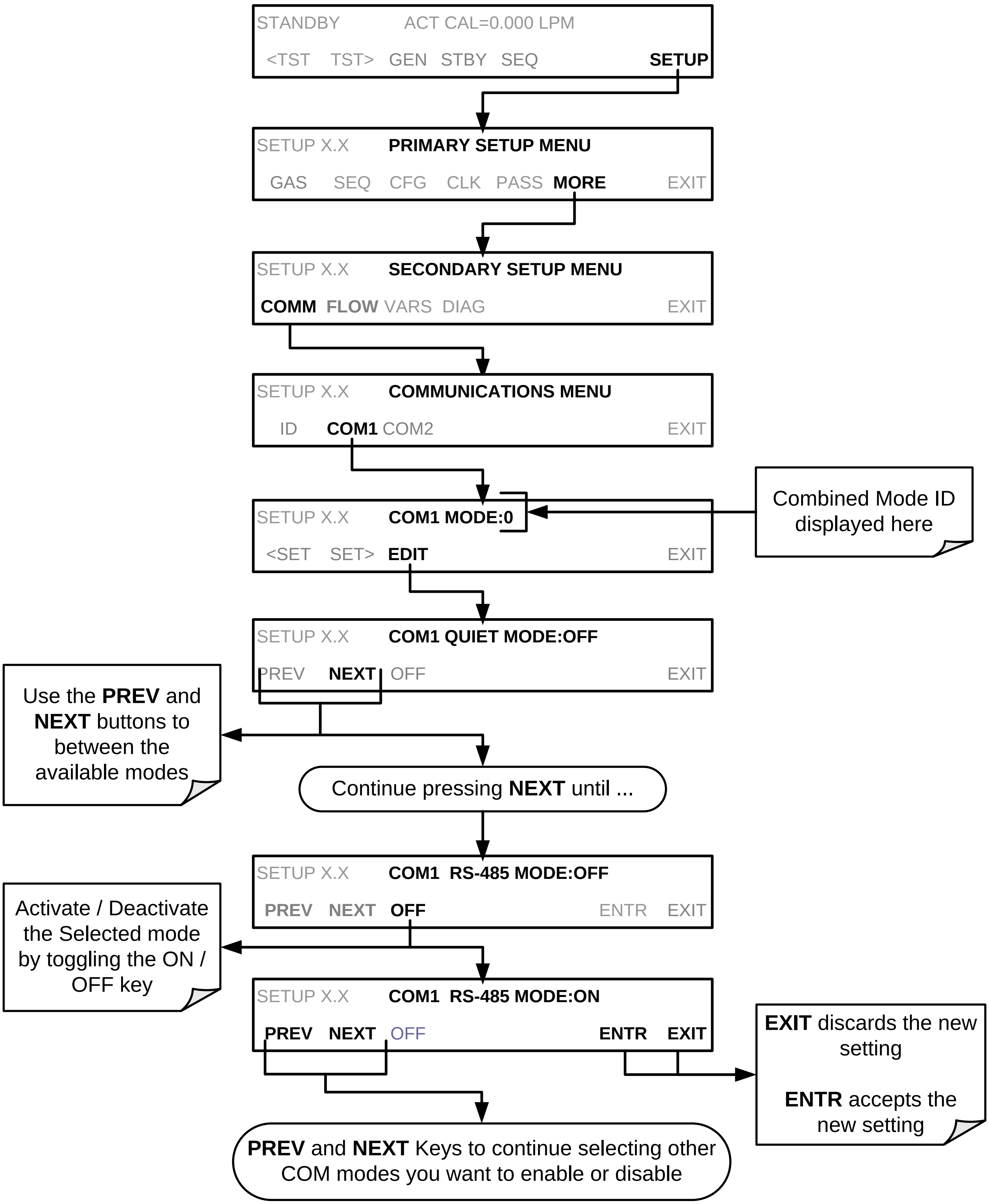
MODE[1]	ID	DESCRIPTION
QUIET	**1**	Quiet mode suppresses any feedback from the calibrator (such as warning messages) to the remote device and is typically used when the port is communicating with a computer program where such intermittent messages might cause communication problems. Such feedback is 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.
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).
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
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.
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 Customer Service personnel.

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

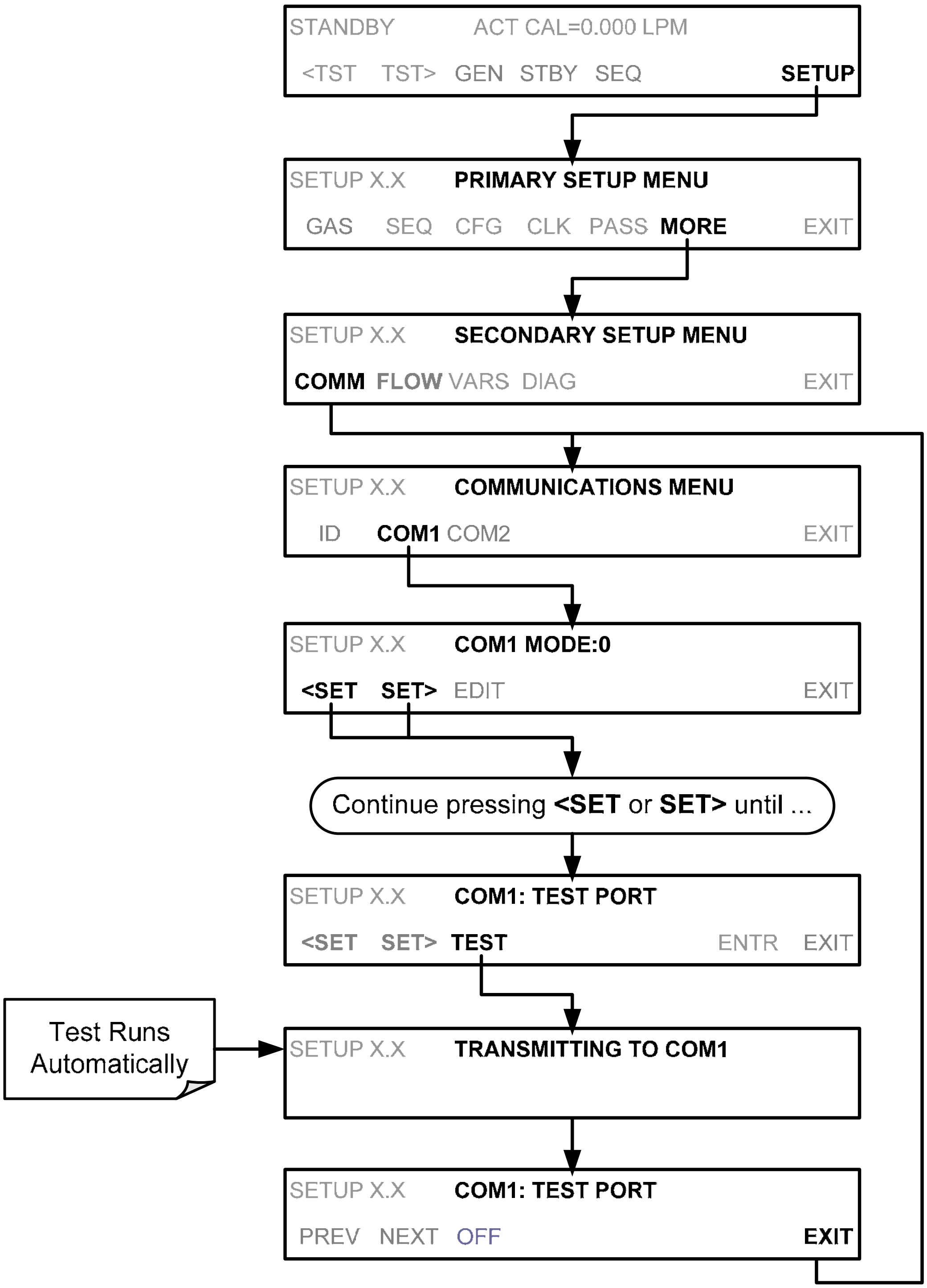
Press the following buttons to select communication modes for a one of the COMM Ports, such as the following example where **RS-485** mode is enabled:



7.1.5. COMM 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 COMM port. While the test is running, the red LED on the rear panel of the calibrator should flicker.

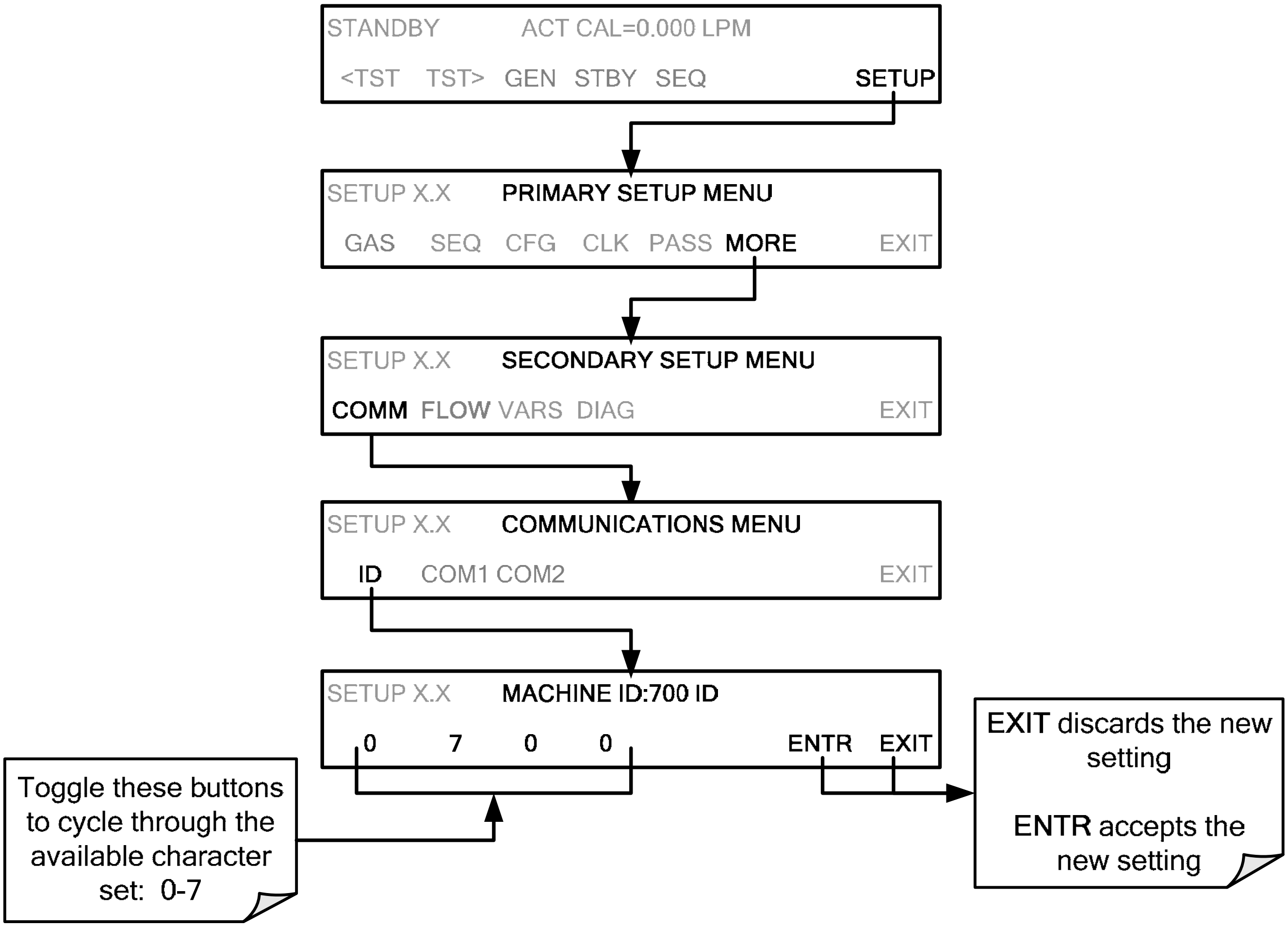
To initiate the test, press the following button sequence:



7.1.6. MACHINE ID

Each type of Teledyne API's calibrator is configured with a default ID code. The default ID code for all T700 calibrators is **700**. 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 7.4); in an RS-232 multi-drop chain (See Section 7.2.1) or operating over a RS-485 network (See Section 7.3). 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 T700'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.

7.1.7. TERMINAL OPERATING MODES

The T700 can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the calibrator supports two communicate modes specifically designed to interface with these two types of devices.

- **Computer mode** is used when the calibrator is connected to a computer with a dedicated interface program.

- **Interactive mode** is used with a terminal emulation programs such as HyperTerminal or a "dumb" computer terminal. The commands that are used to operate the calibrator in this mode are listed in Table 7-2.

7.1.7.1. Help Commands in Terminal Mode

Table 7-2: 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 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.

7.1.7.2. 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 7-3 and Appendix A-6.

[ID] is the machine identification number (Section 7.1.6). 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 7-3: Teledyne API Serial I/O Command Types

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

7.1.7.3. 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.

7.1.7.4. 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 7.1.4, Table 7-1).

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.

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 7-3.
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 front panel display does not give any information on the time a message was issued, hence it is useful to log such messages for trouble-shooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

7.1.7.5. COMM Port Password Security

In order to provide security for remote access of the T700, 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 7.1.4). 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 T700 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.

7.2. REMOTE ACCESS BY MODEM

The T700 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:

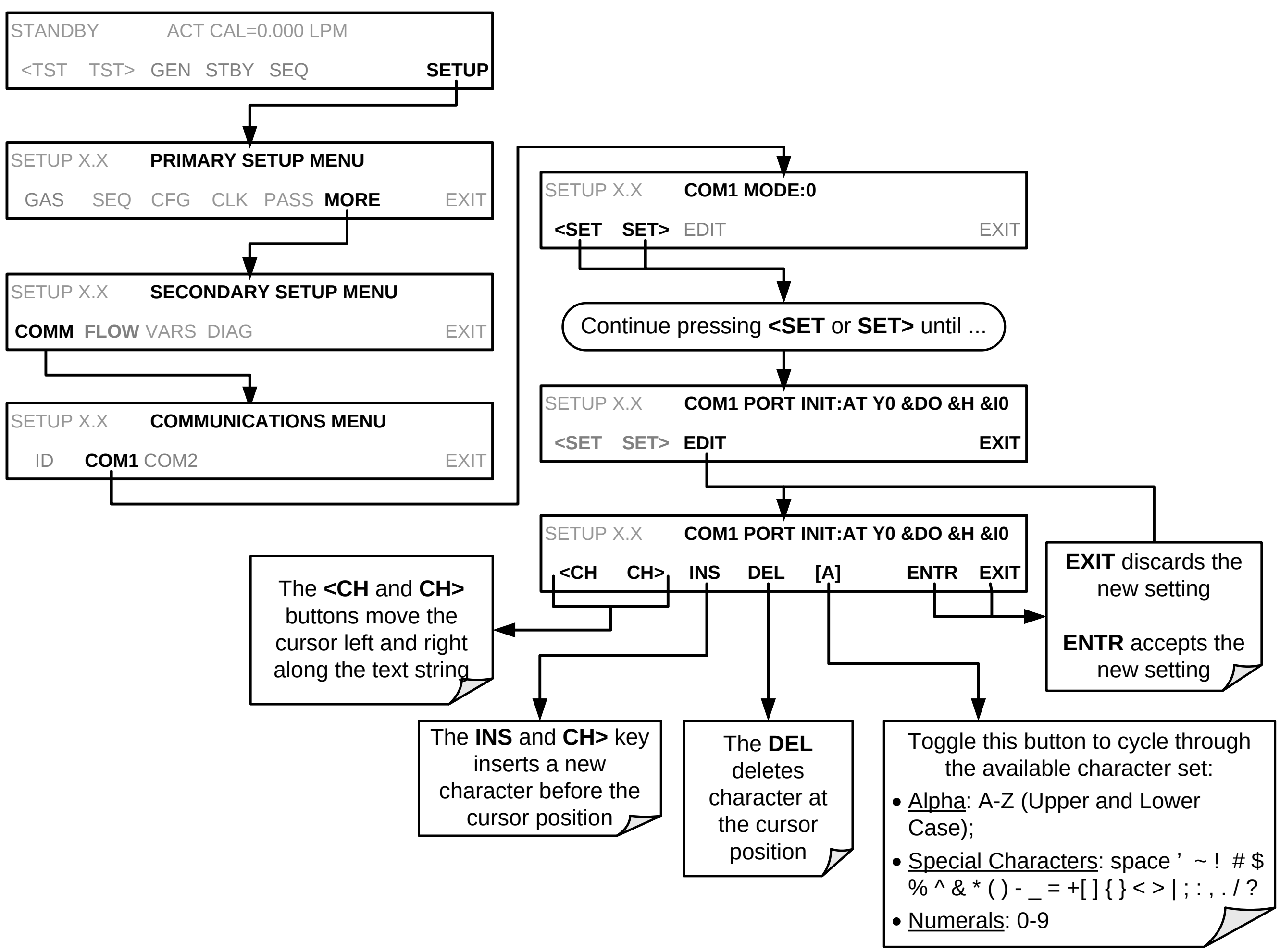
- The DTE-DCE is in the DCE position.
- The T700 COMM port is set for a baud rate that is compatible with the modem.
- The Modem is designed to operate with an 8-bit word length with one stop bit.
- The **MODEM ENABLE** communication mode is turned **ON** (Mode 64, see Section 7.1.4).

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:

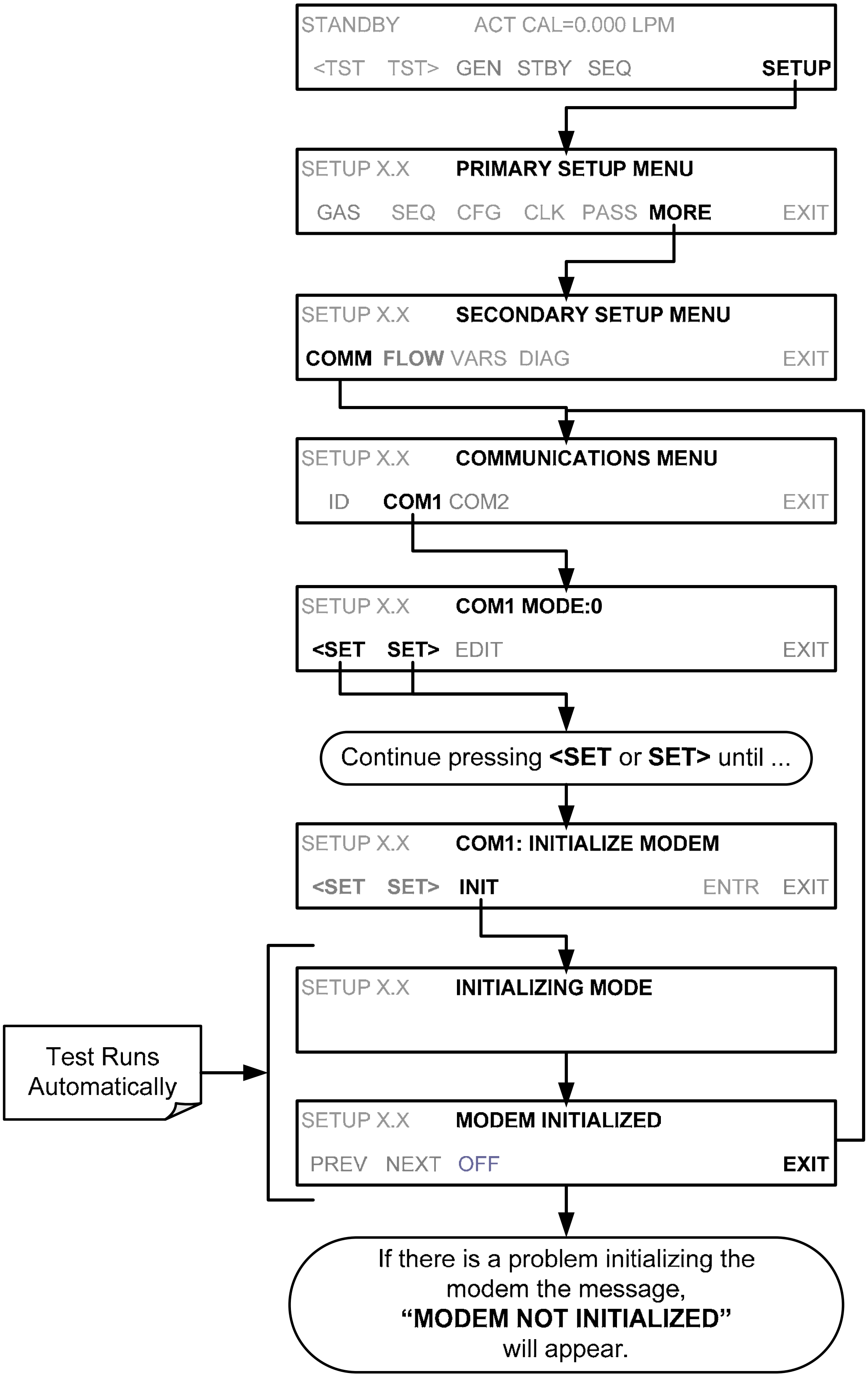
AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0

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:



7.2.1. MULTI-DROP RS-232 SET UP

The RS-232 multi-drop consists of a Printed Circuit Assembly (PCA) that is seated on the calibrator's CPU card (Figure 7-3) with cabling to connect it to the calibrator's motherboard. This PCA includes all circuitry required to enable your calibrator for multi-drop operation. It converts the instrument's RS232 port to multi-drop configuration allowing up to eight Teledyne API's T-Series calibrators or analyzers to be connected over a chain of RS-232 cables to the same I/O port of the host computer.

Because both of the DB9 connectors on the calibrator's back panel are needed to construct the multi-drop chain, COM2 is no longer available for separate RS-232 or RS-485 operation.

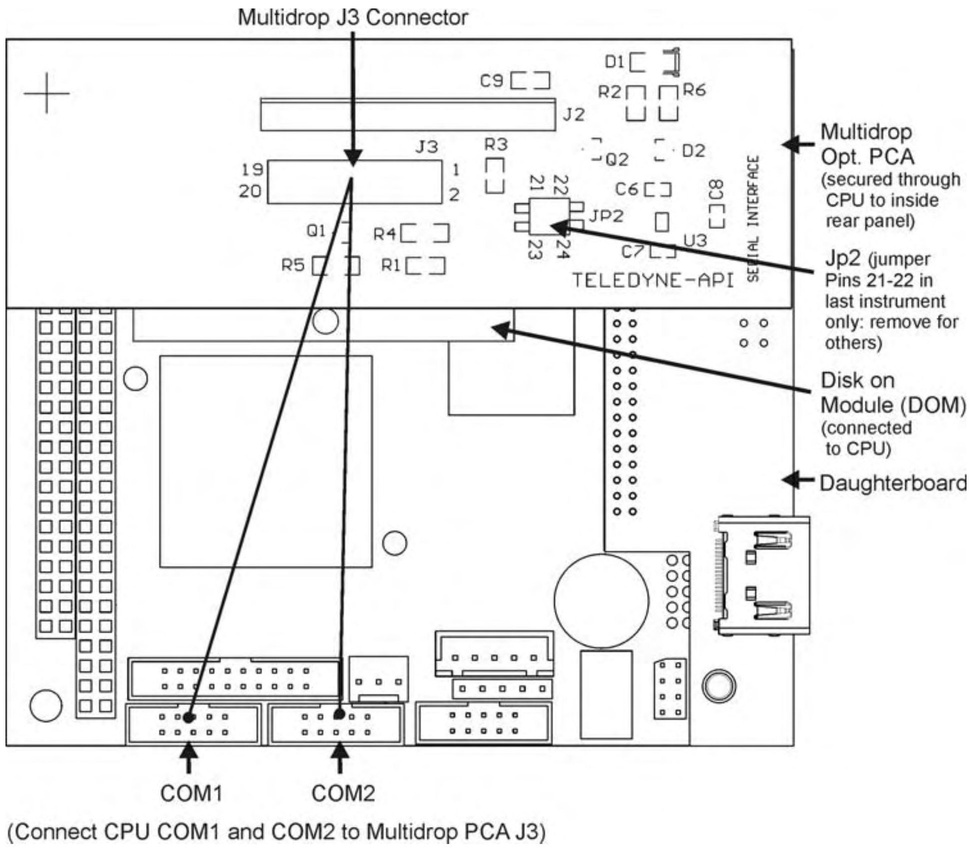


Figure 7-3: Location of JP2 on RS232-Multi-drop PCA (Option 62)

Each calibrator or analyzer in the multi-drop chain must have:

- One Teledyne API's Option 62 installed.
- One 6' straight-through, DB9 male → DB9 Female cable (Teledyne API's P/N WR0000101) is required for each calibrator.

To set up the network, for each instrument:

1. With NO power to the instrument, remove its top cover and locate JP2 on the multidrop PCA, which is assembled with a shunt that jumpers Pins 21 → 22 (Figure 7-3).
2. Remove and store the shunt (place the shunt on one pin only) for all instruments in the network except the instrument that is to be the last: make sure a shunt is in place connecting Pins 21 → 22 for the last instrument.

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 PCA in the instrument that was previously the last instrument in the chain.

3. Close the instrument.
4. Using straight-through, DB9 male → DB9 Female cable, interconnect the host and the analyzers as shown in Figure 7-4.
5. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each. (This ID is also called the Hostname; see Section 7.4.2). On the front panel menu, use SETUP>MORE>COMM>ID. Note that the default ID is typically the model number; to change the 4-digit identification number, press the button of the digit to be changed).Figure 7-4.

NOTE:

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

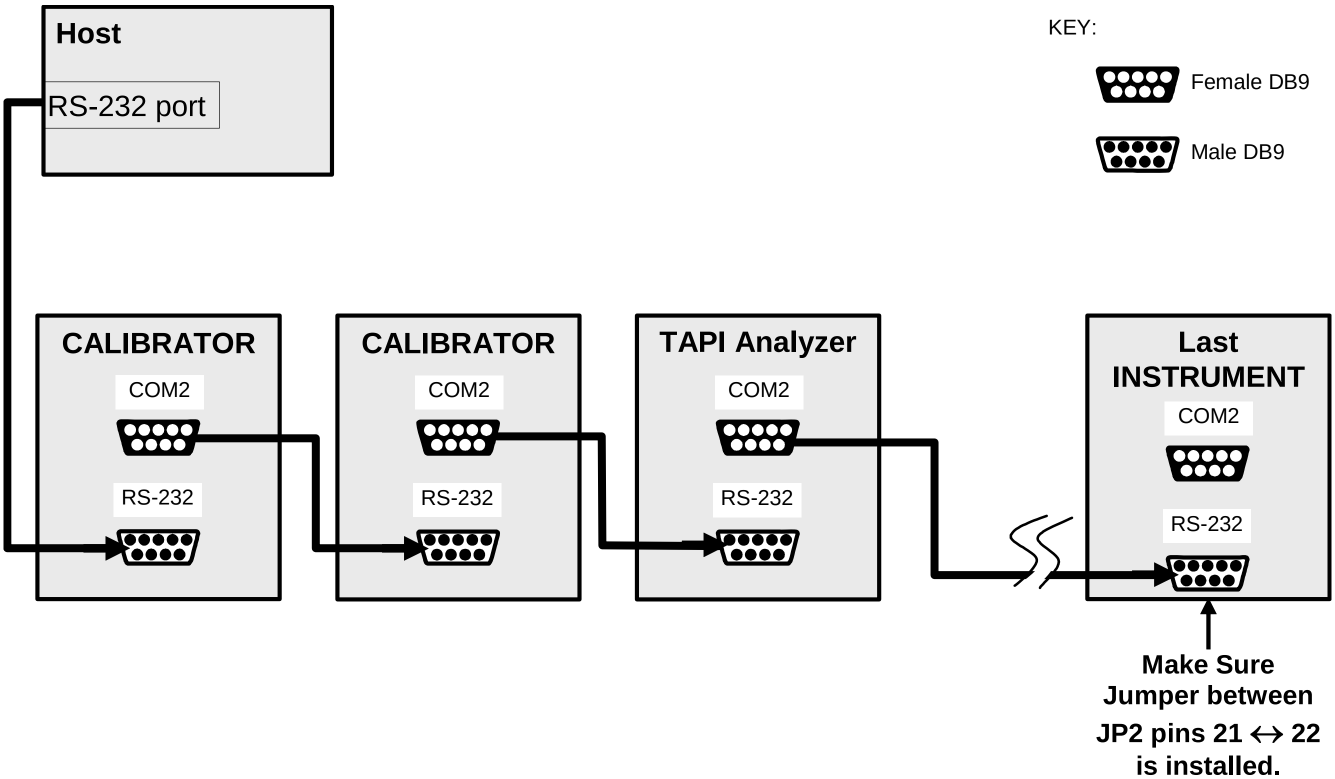


Figure 7-4: RS-232 Multi-drop PCA Host/Calibrator Interconnect Diagram

7.3. RS-485 CONFIGURATION OF COM2

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 capable of supporting up to 32 instruments with a maximum distance between the host and the furthest instrument being 4000 feet. If you require full duplex or isolated operation, please contact Teledyne API's Customer Service.

To reconfigure **COM2** as an RS-485 port:

1. Locate J32 and move the shunt from Pins 1 ↔ 2 to Pins 3 ↔ 4.
2. Remove the connector from J12.
3. Plug the RS-485 connector into J15.

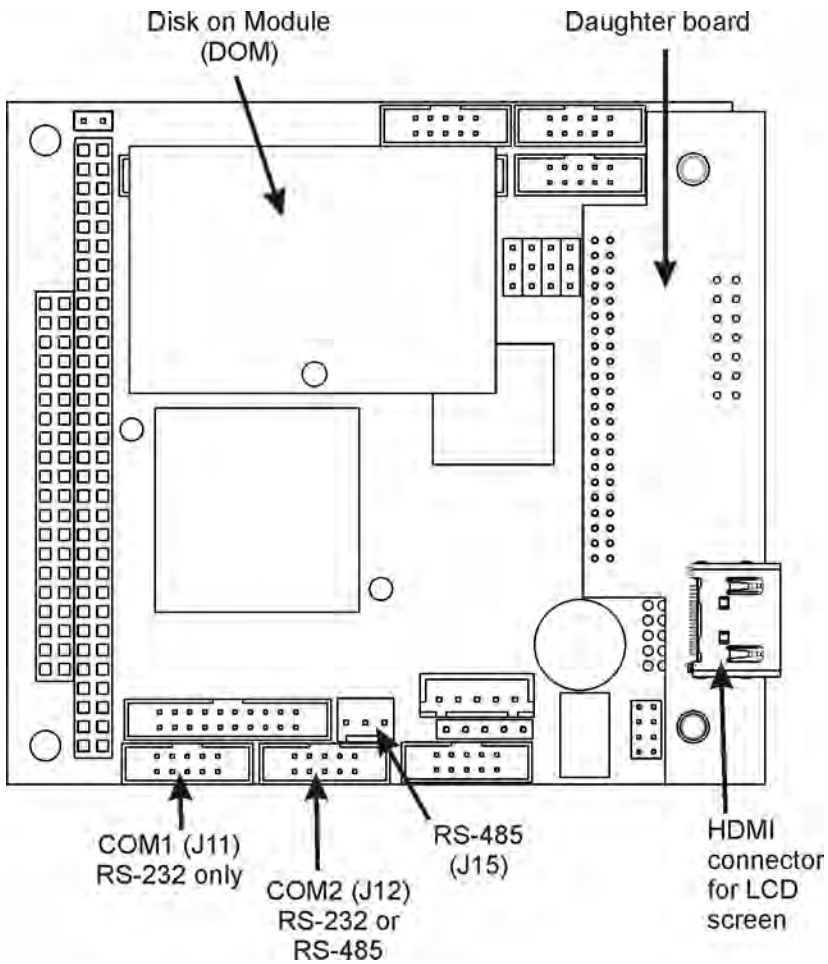


Figure 7-5: CPU Card Locations of RS-232/485 Switches, Connector

When COM2 is configured for RS-485 operation the port uses the same female DB-9 connector on the back of the instrument as when COM2 is configured for RS-232 operation, however, the pin assignments are different.

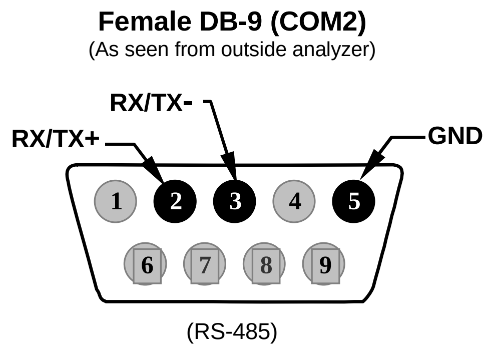


Figure 7-6: Back Panel connector Pin-Outs for COM2 in RS-485 Mode

The signal from this connector is routed from the motherboard via a wiring harness to a 3-pin connector on the CPU card, J15.

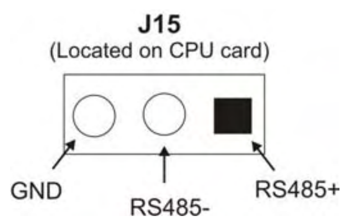


Figure 7-7: CPU Connector Pin-Outs for COM2 in RS-485 Mode

7.4. 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 7.4.1), but for a permanent Ethernet connection, configure the instrument with a static IP address (Section 7.4.1.1).

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

Table 7-4: Ethernet Status Indicators

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

7.4.1. CONFIGURING THE ETHERNET INTERFACE USING DHCP

The Ethernet feature for your T700 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

It is a good idea to 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 you network server(s).

Table 7-5: LAN/Internet Configuration Properties

PROPERTY	DEFAULT STATE		DESCRIPTION
DHCP STATUS	On	Editable	This displays whether the DHCP is turned ON or OFF.
INSTRUMENT IP ADDRESS	Configured by DHCP	**EDIT** button disabled when DHCP is **ON**	This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the calibrator itself.
GATEWAY IP ADDRESS	Configured by DHCP	**EDIT** button disabled when DHCP is **ON**	A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	Configured by DHCP	**EDIT** button disabled when DHCP is **ON**	Also, a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that defines that identifies the LAN 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**	Editable, but **DO NOT CHANGE**	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	**T700**	Editable	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 T700 calibrators is "T700", the host name may be changed to fit customer needs.

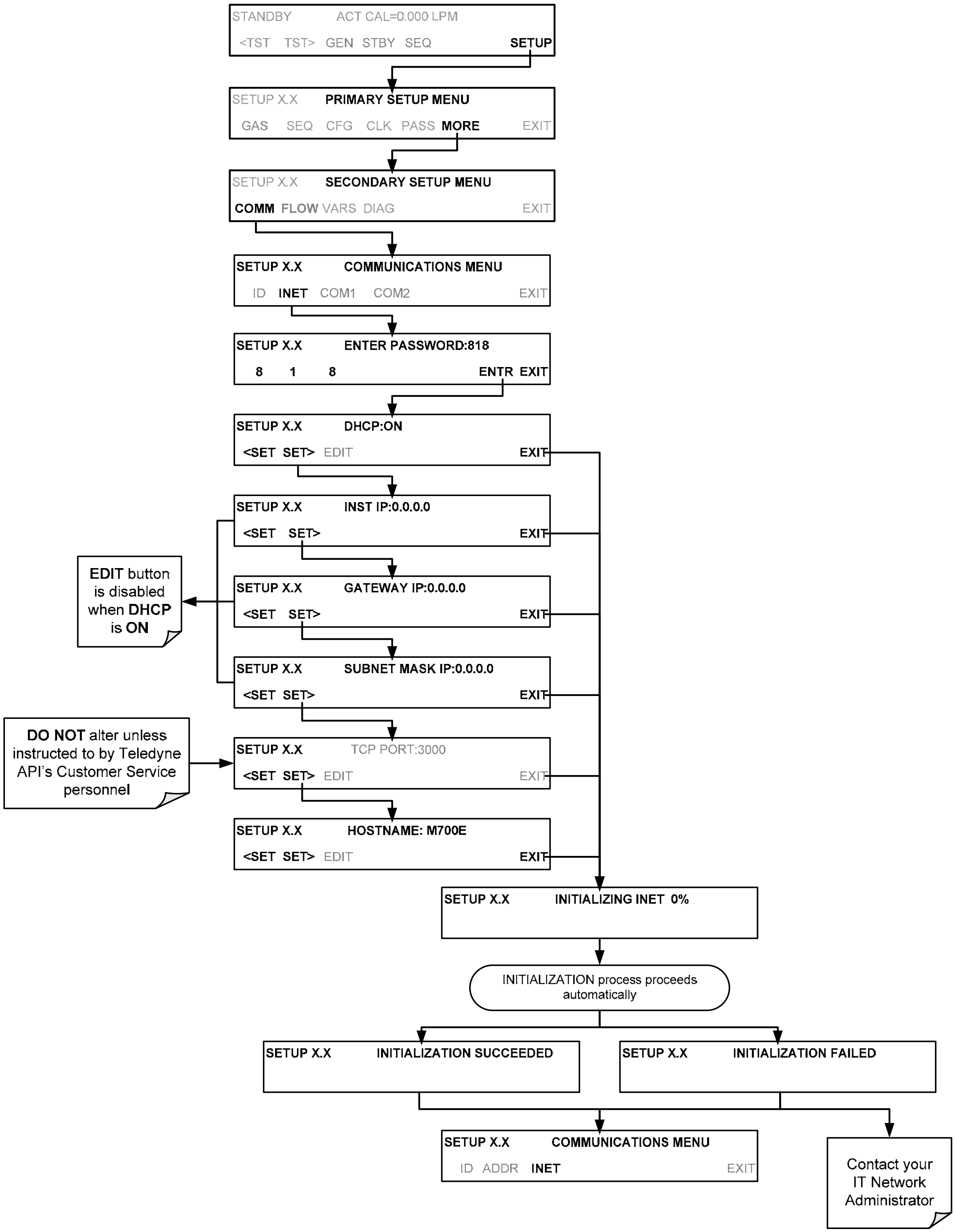
[1] Do not change the setting for this property unless instructed to by Teledyne API's Customer Service personnel.

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 7-5, press:

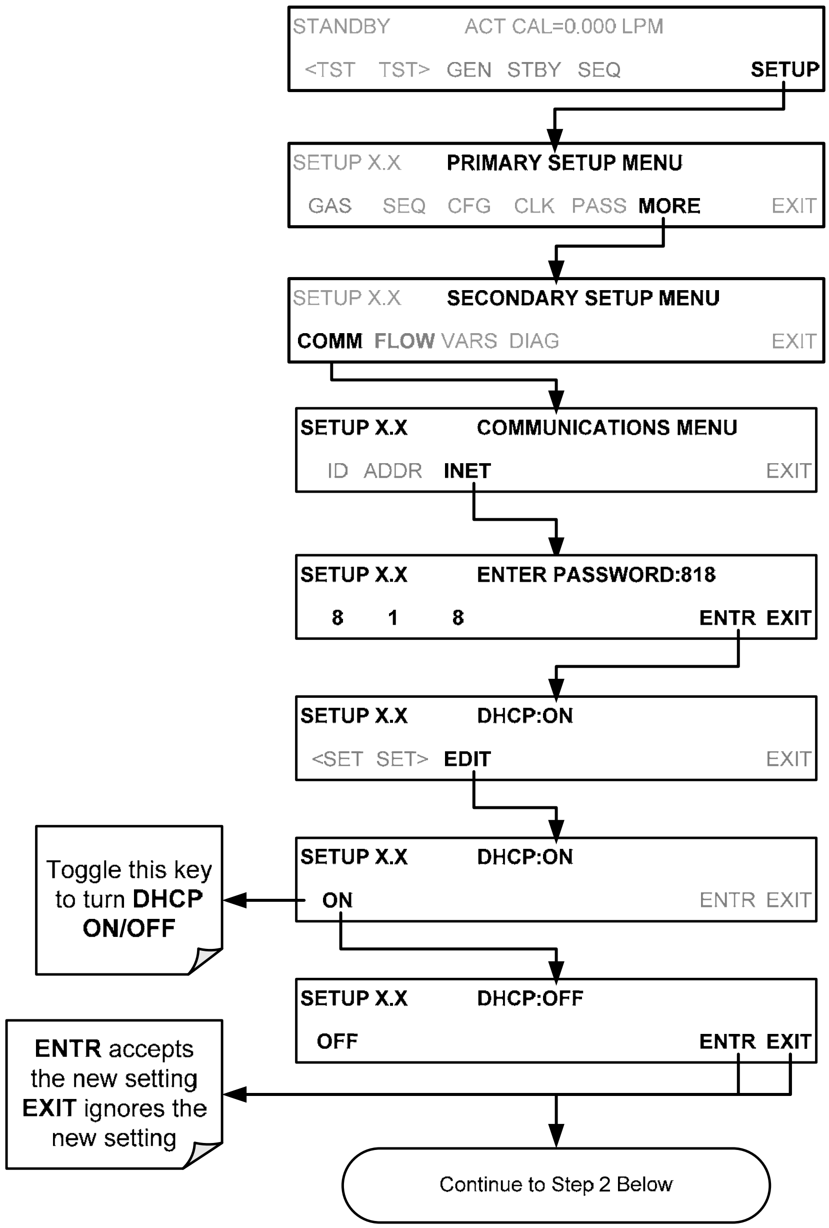


7.4.1.1. Manually Configuring the Network IP Addresses

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

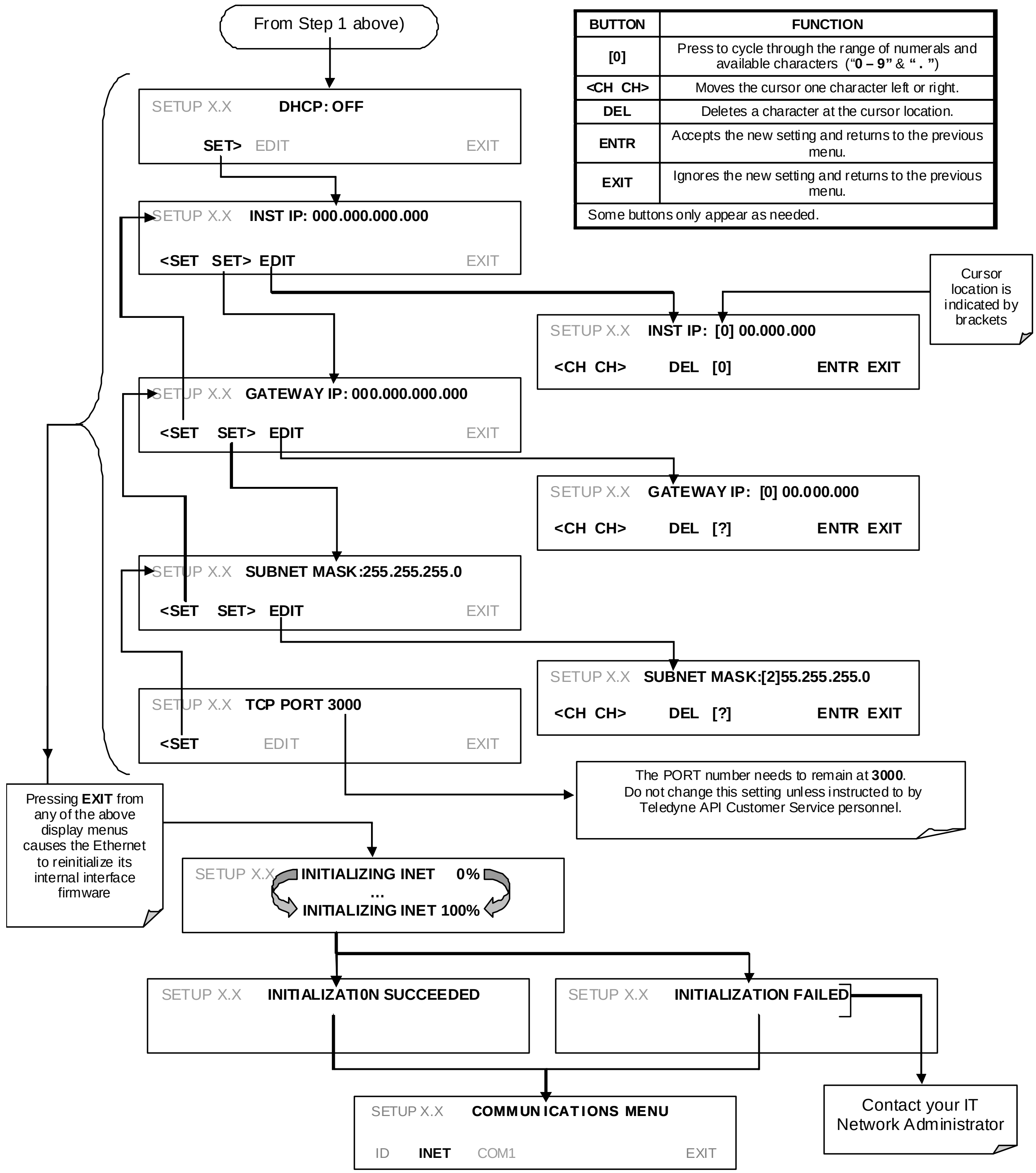
- Your LAN is not running a DHCP software package,
- The DHCP software is unable to initialize the calibrator's interface;
- You wish to configure the interface with a specific IP address, such as for a permanent Ethernet connection..

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



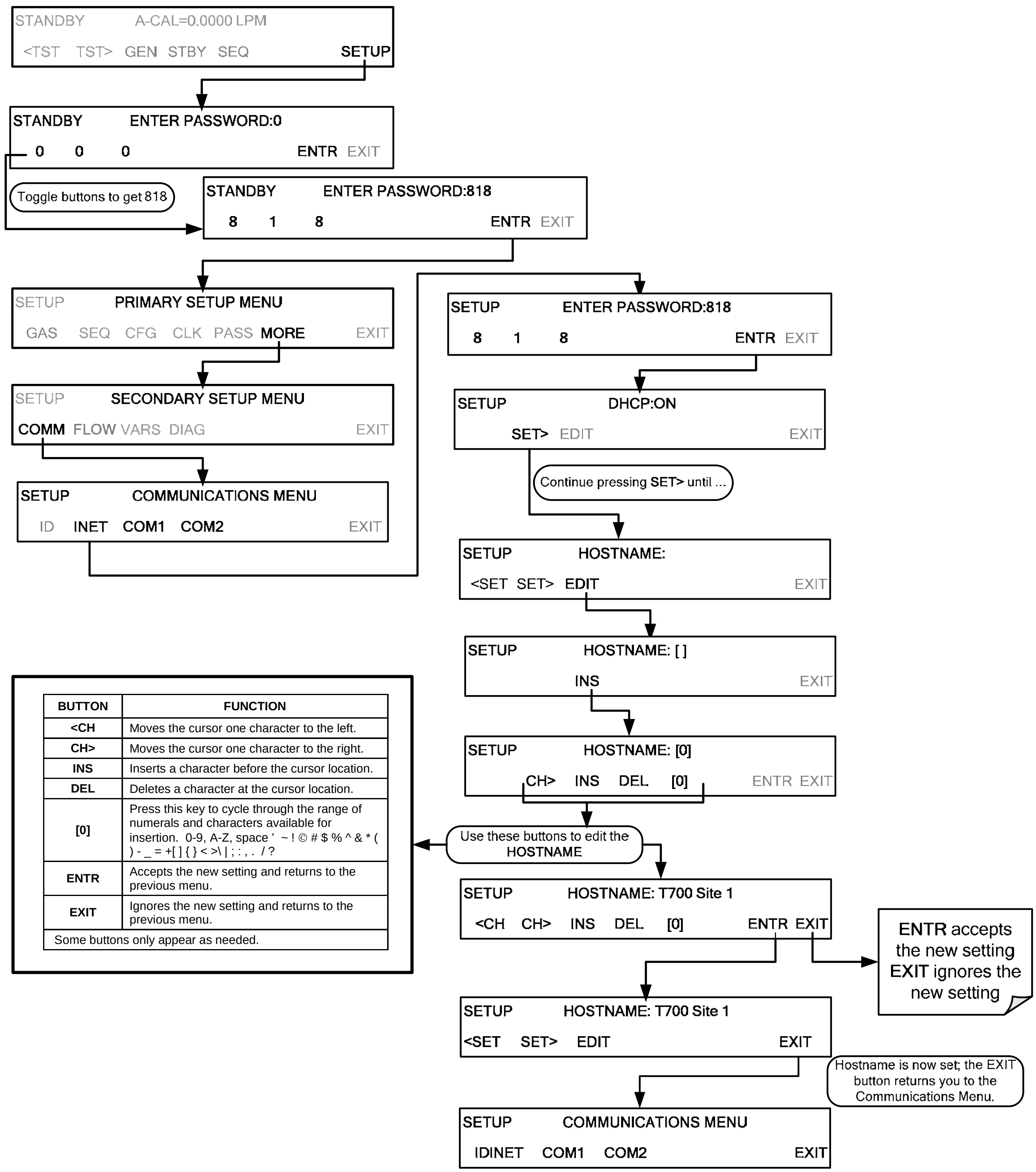
Internet Configuration Touchscreen Button Functions

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 as needed.	



7.4.2. 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 T700 calibrators is **T700**. To change this name (particularly if you have more than one T700 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 as needed.	

7.5. APICOM REMOTE CONTROL PROGRAM

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 T700 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and trouble-shooting. Figure 7-8 shows an example of APICOM's main interface, which emulates the look and functionality of the instruments actual front panel.

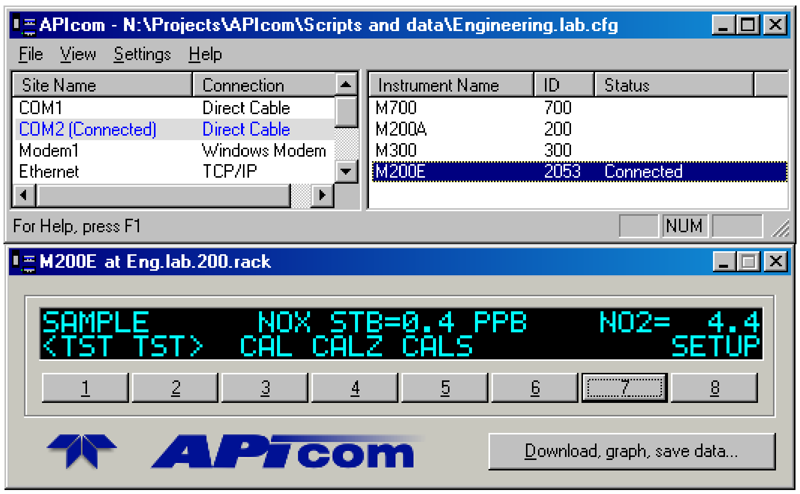


Figure 7-8: APICOM Remote Control Program Interface

NOTE

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

The T700 calibrator is fully supported by APICOM revision 5 and later.

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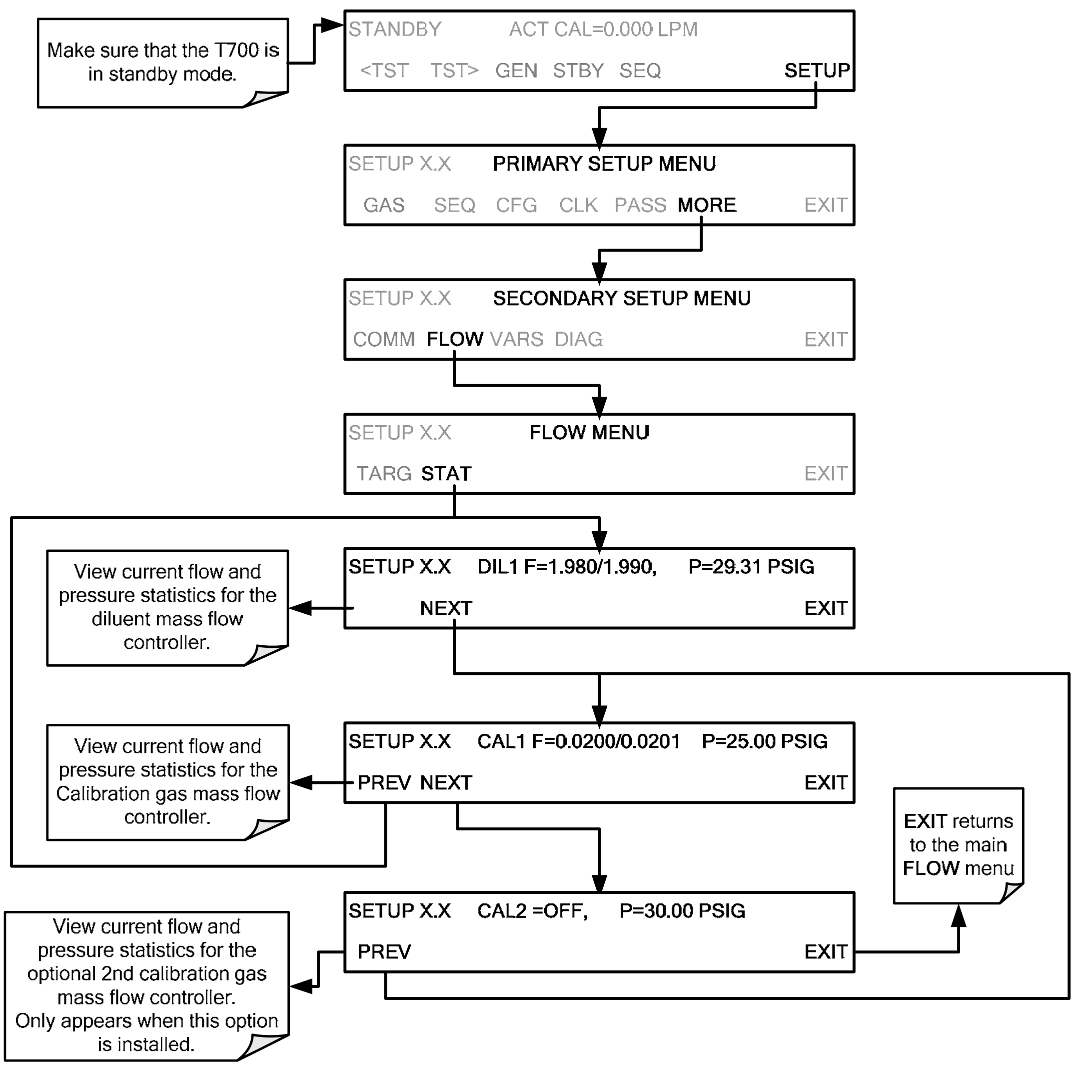
8. CALIBRATION AND VERIFICATION

Basic electronic calibration of the T700 Dynamic Dilution 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 8.1 and 8.2).
- O_3 Photometer: If your T700 is equipped with the optional O_3 photometer its performance should be periodically verified against and external transfer standard (see Section 8.3).
- O_3 Generator: If your T700 is equipped with the optional O_3 generator, it should be periodically calibrated (see Section 8.4).

8.1. VIEWING THE PERFORMANCE STATISTICS FOR THE T700'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 T700 calibrator (in real time). To access this information, press:



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.

8.2. CALIBRATING THE OUTPUT OF THE T700'S MFC'S

A table exists in the memory of the T700'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 8.2.2).

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 MFC's by adjusting either the control voltage of a point or its associated flow output value (see Section 8.2.2).

Table 8-1: 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	3150 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

8.2.1. SETUP FOR VERIFICATION AND CALIBRATION OF THE T700'S MFC'S

NOTE

A separate flow meter is required for the procedure.

1. Turn off the T700 Dynamic Dilution Calibrator.
2. Open the front panel to the T700 calibrator. This is the easiest access to the MFC output ports.
   - A locking screw located at the top center of the front panel (See Figure 3-1) must be removed before the panel can be opened.
3. Attach the flow meter directly to the output port of the MFC to be checked/tested.

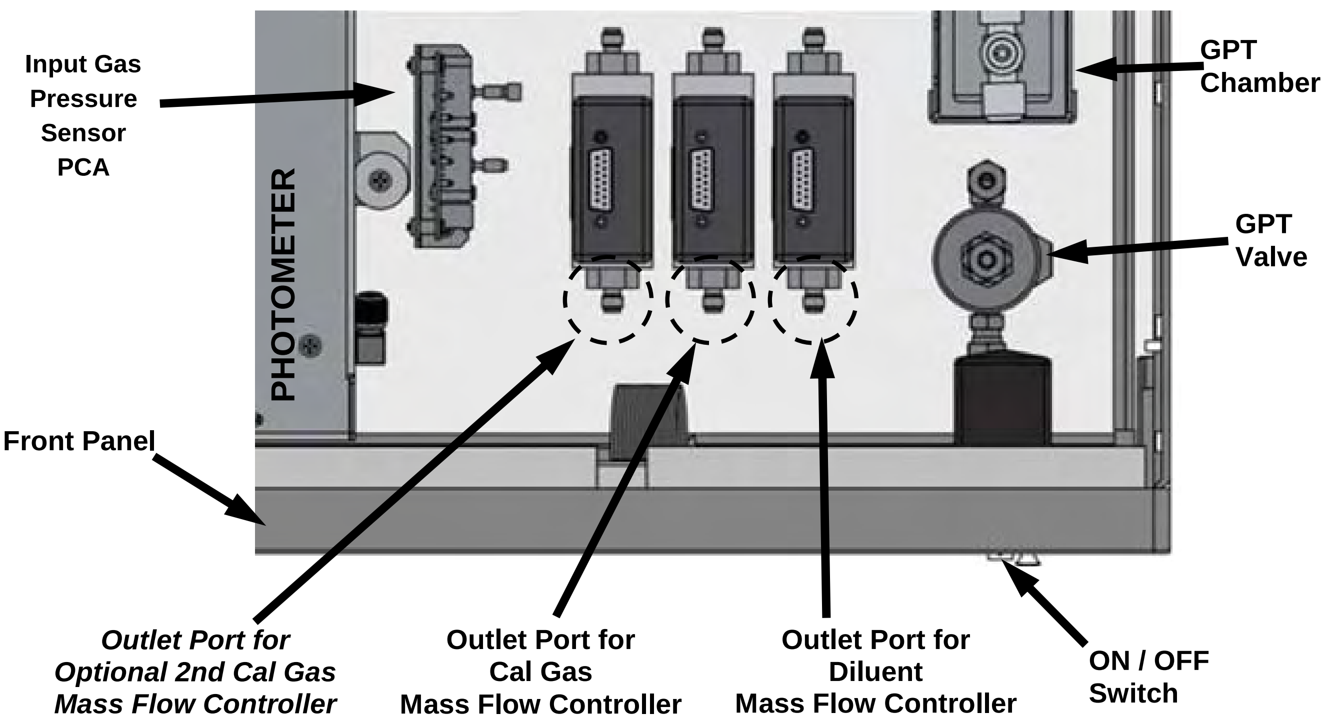
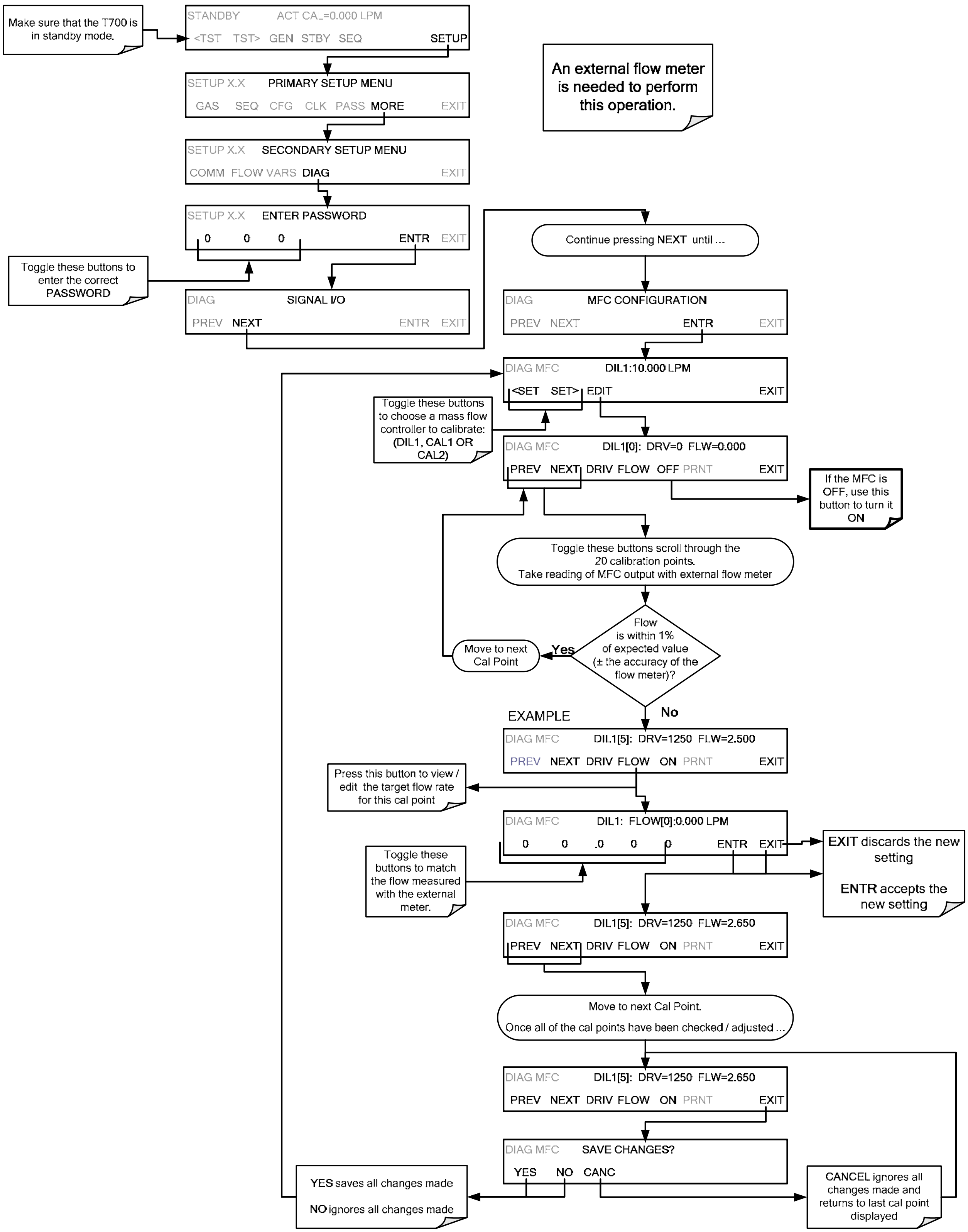


Figure 8-1: Location of MFC Outlet Ports

4. Turn the T700 Dynamic Dilution Calibrator ON.

8.2.2. VERIFYING AND CALIBRATING THE T700'S MFC'S

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



8.3. VERIFYING AND CALIBRATING THE T700'S OPTIONAL O_3 PHOTOMETER

For calibrators equipped with the O_3 photometer, the accuracy of calibration mixtures involving O_3 produced by the T700 depends entirely on the accuracy of the photometer, therefore it is very important that the photometer is operating properly and accurately. Setup for Verifying O_3 Photometer Performance is shown in Section 8.3.1.

8.3.1. SETUP FOR VERIFYING O_3 PHOTOMETER PERFORMANCE

NOTE

This operation requires an external reference photometer.

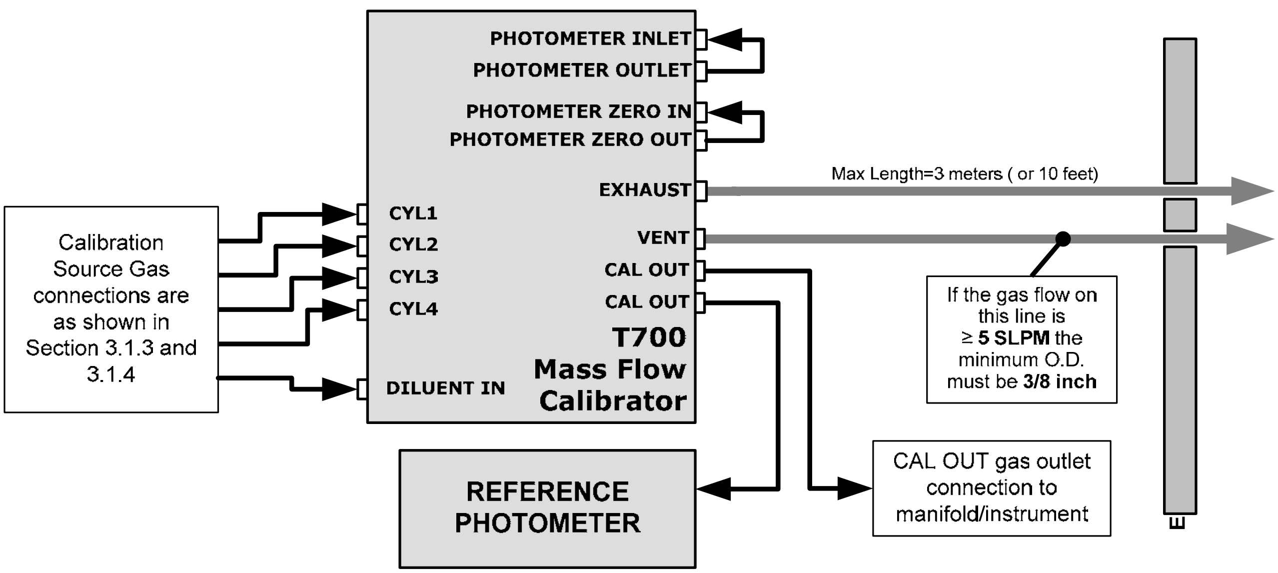
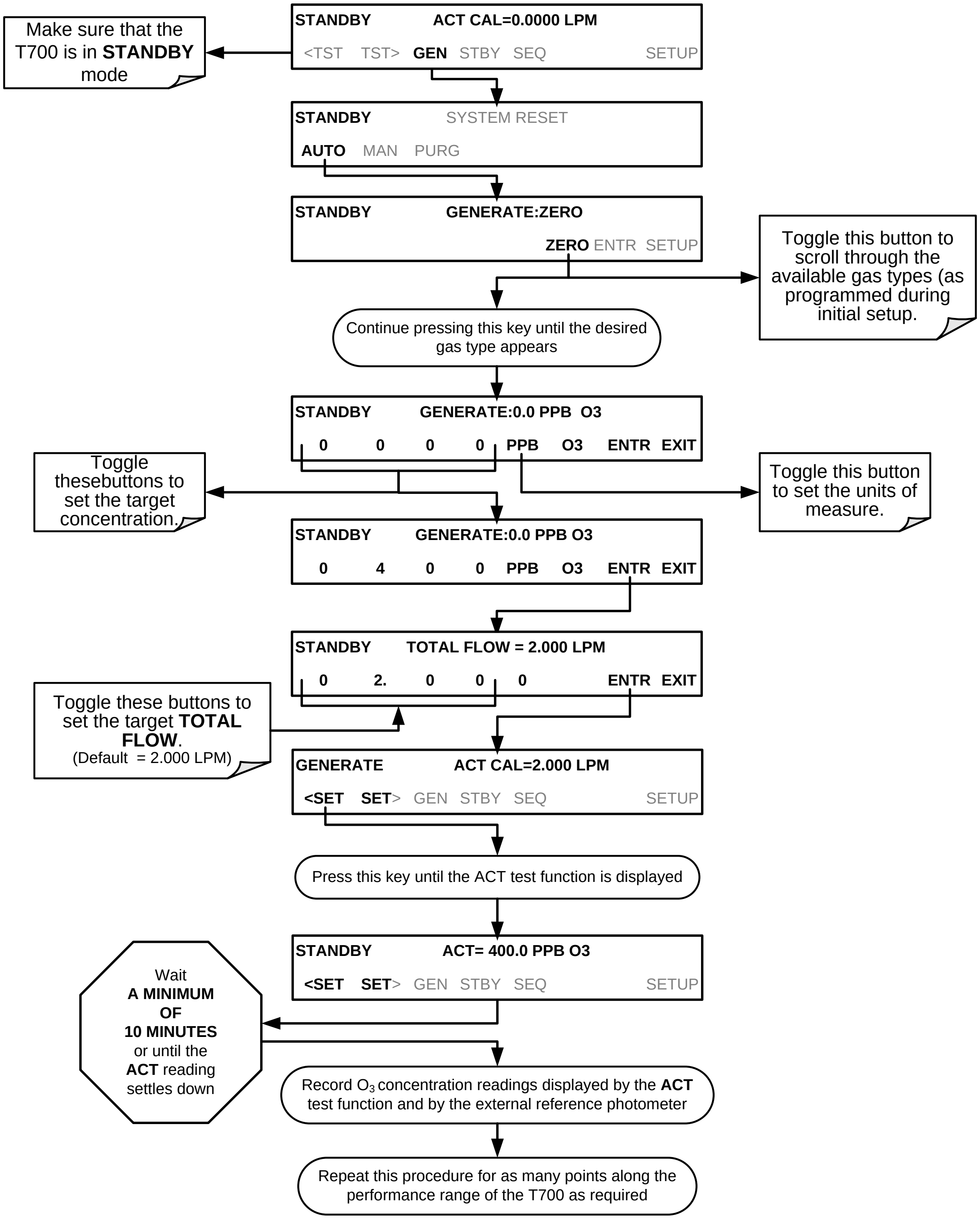


Figure 8-2: Set up for Verifying Optional O_3 Photometer

8.3.2. VERIFYING O_3 PHOTOMETER PERFORMANCE

To verify the performance of the T700's optional internal photometer perform the following steps:



NOTE

The readings recorded from the T700's ACT test function and the reference photometer should be within 1% of each other.

8.3.3. 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 T700 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 T700 calibrator.

8.3.3.1. Setup Using Direct Connections

Figure 8-3 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 T700 Calibrator.

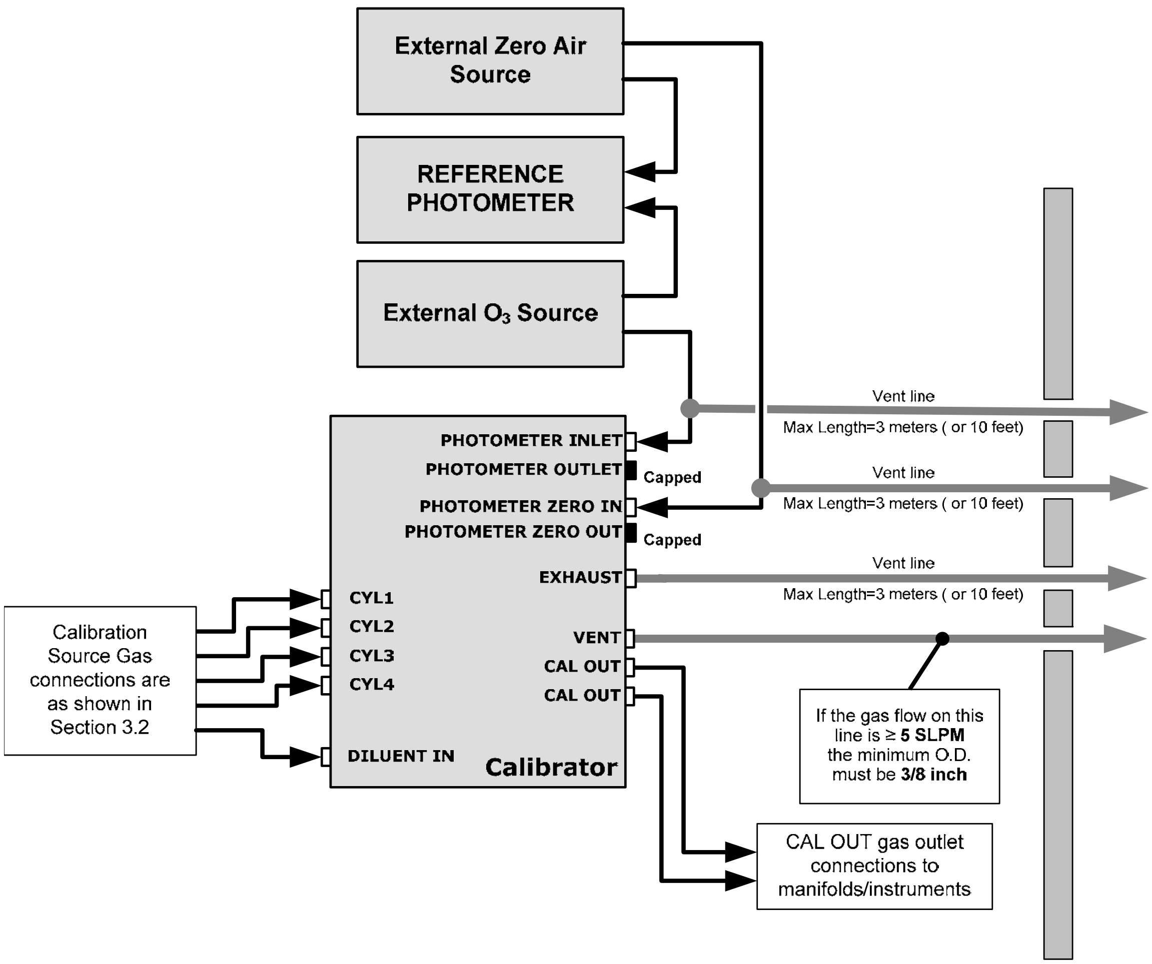


Figure 8-3: External Photometer Validation Setup – Direct Connections

NOTE

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

8.3.3.2. Setup Using a Calibration Manifold

Figure 8-4 shows the external zero air and O_3 sources as well as the reference photometer connected to the T700 Calibrator via calibration manifolds for both zero air and O_3.

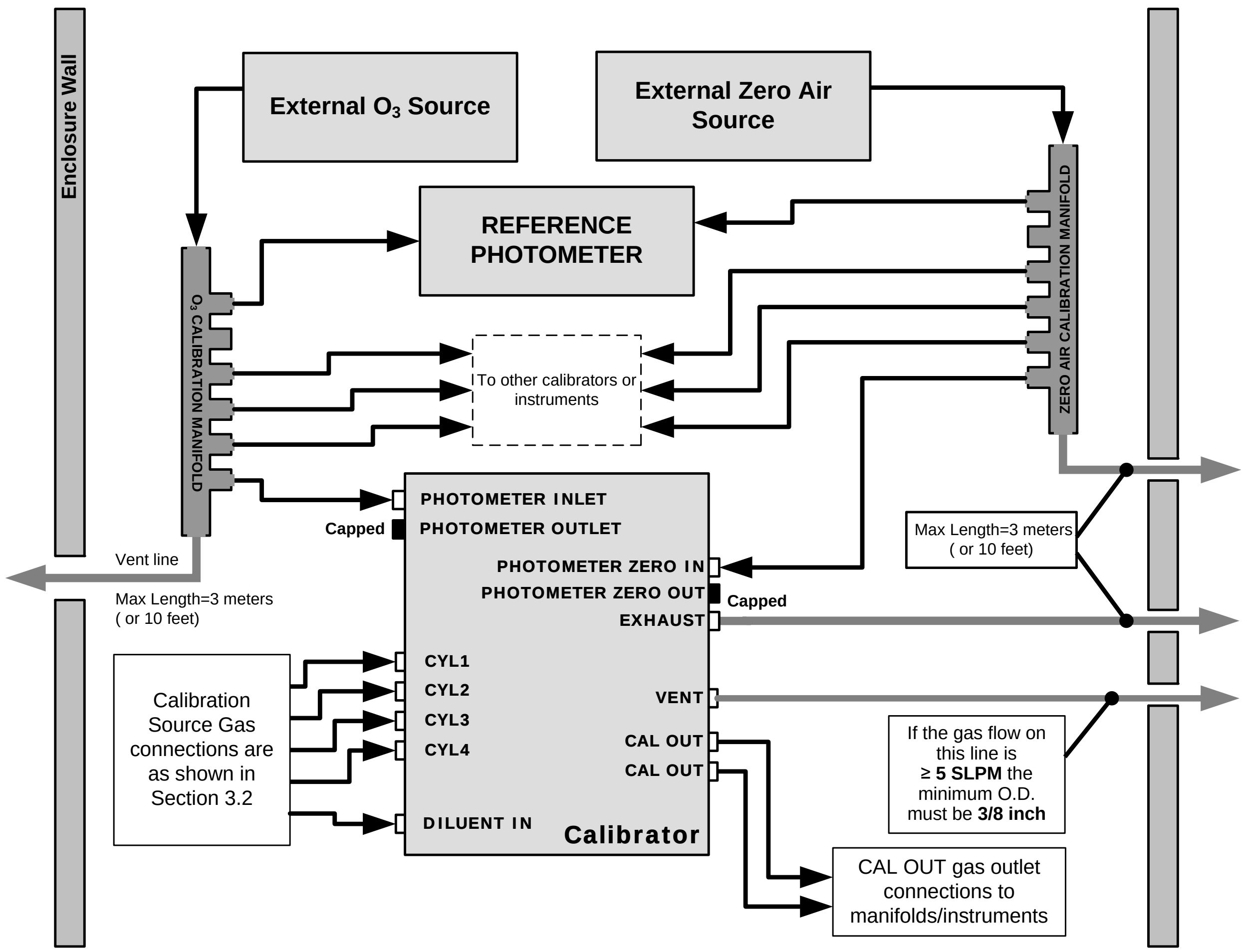


Figure 8-4: External Photometer Validation Setup with Calibration Manifolds

> **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.**

8.3.3.3. Calibration Manifold Exhaust/Vent Line

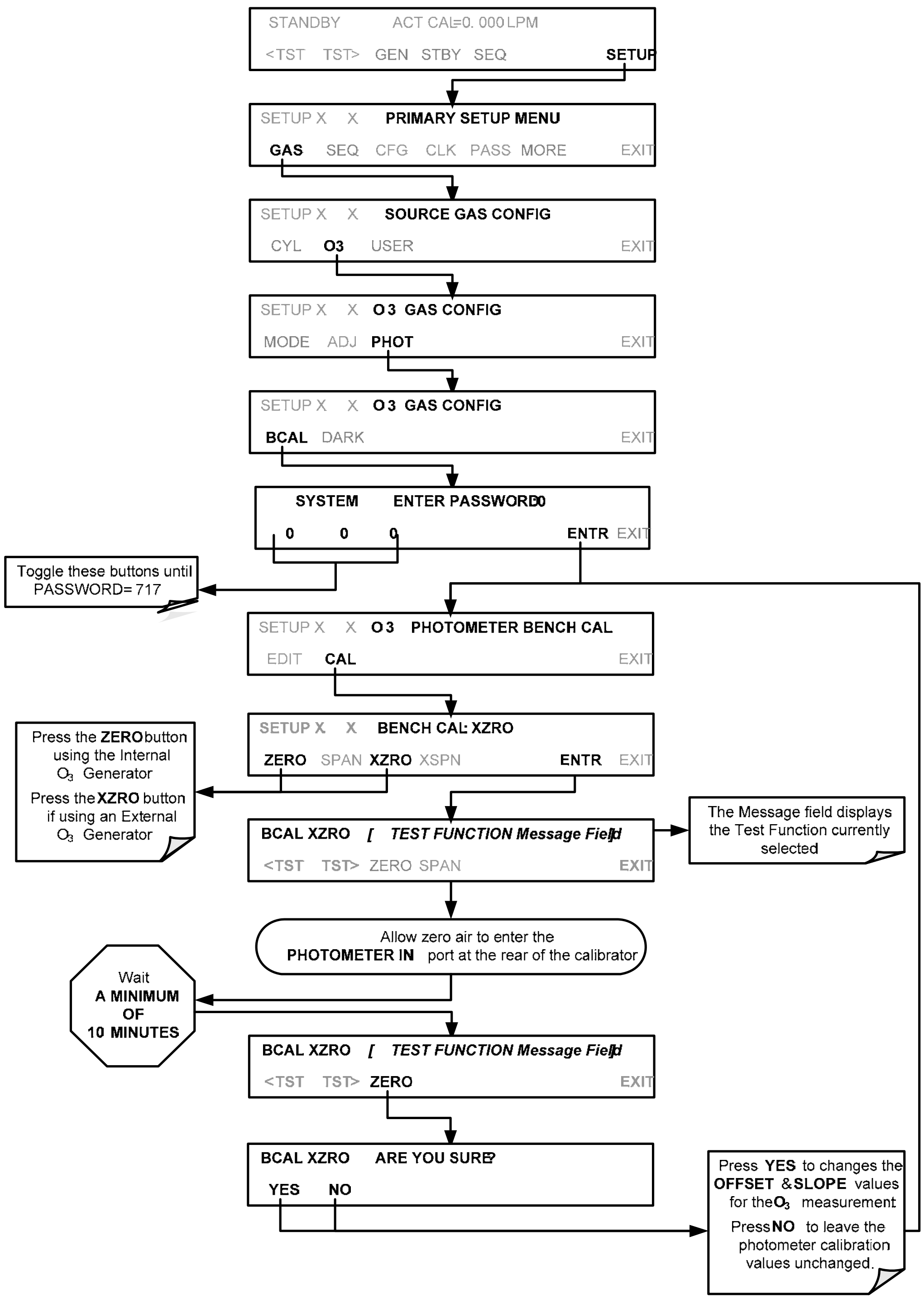
The manifold's excess gas should be vented to a suitable vent outside of the room. The internal diameter of this vent should be large enough to avoid any appreciable pressure drop, and it must be located sufficiently downstream of the output ports to ensure that no ambient air enters the manifold due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

8.3.4. PERFORMING AN EXTERNAL CALIBRATION OF THE O_3 PHOTOMETER

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

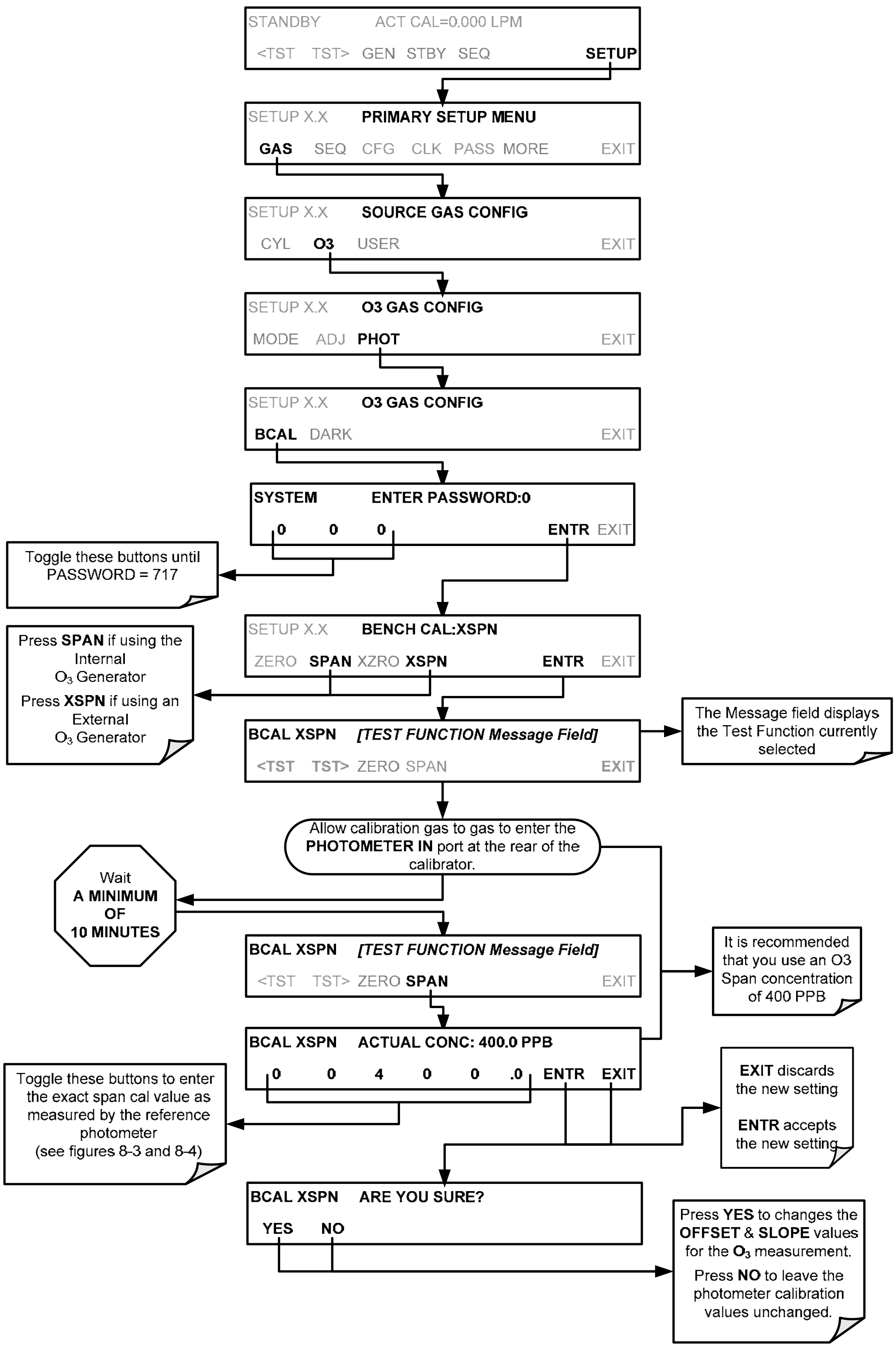
8.3.4.1. Photometer Zero Calibration

To set the zero point offset for the T700 Dynamic Dilution Calibrator's photometer, press:



8.3.4.2. Photometer Span Calibration

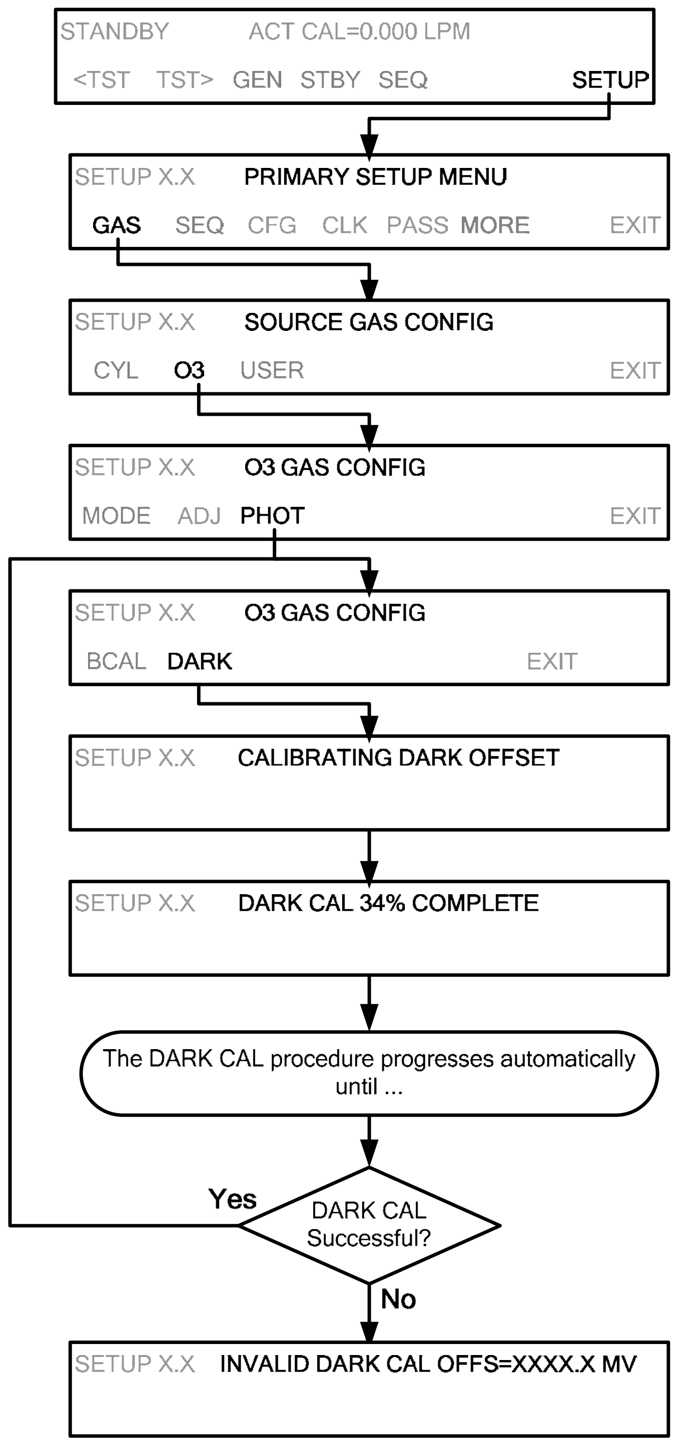
To set the response SLOPE for the T700 Dynamic Dilution Calibrator's photometer, press:



8.3.5. 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:



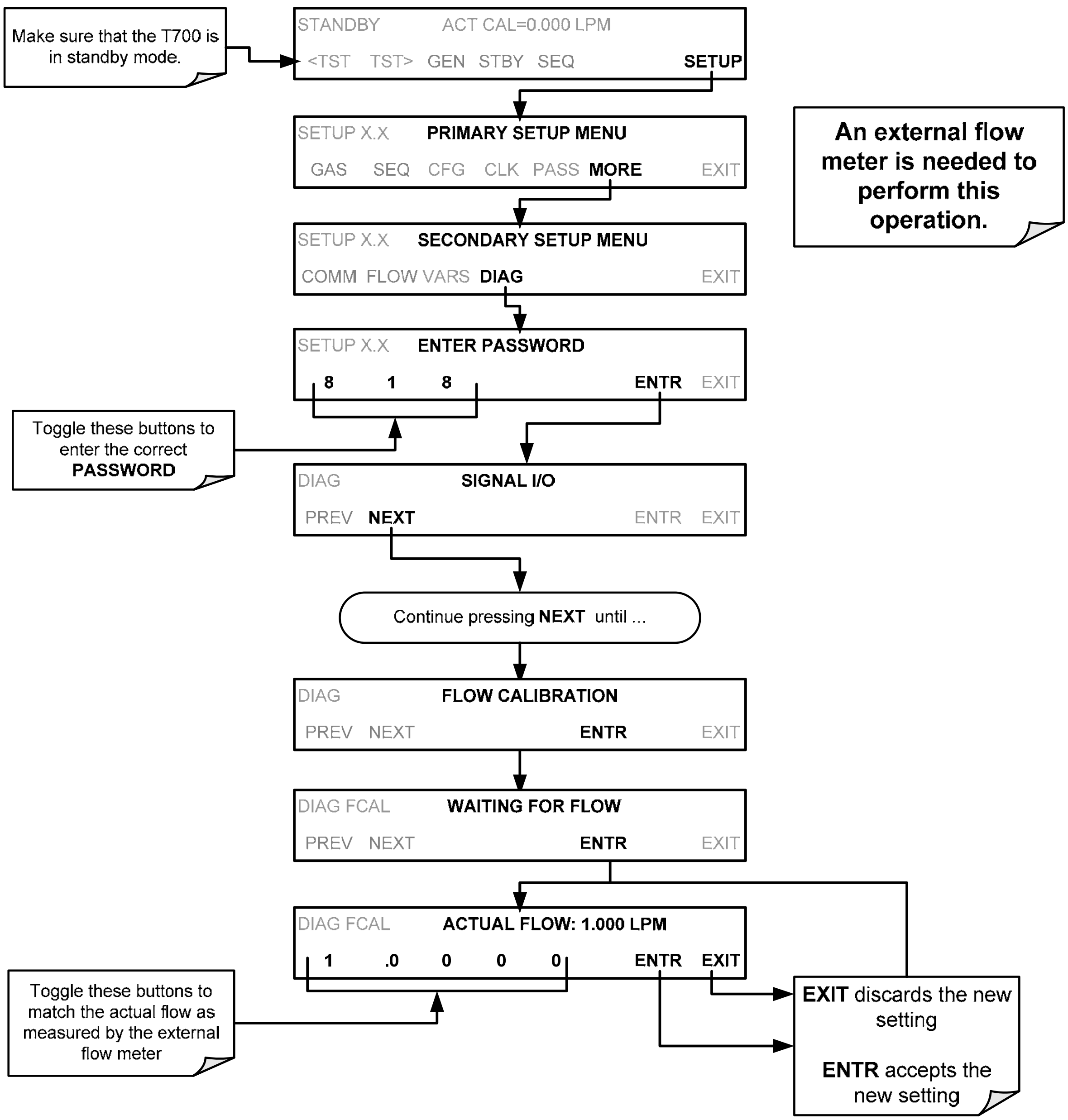
8.3.6. O_3 PHOTOMETER GAS FLOW CALIBRATION

NOTE

A separate flow meter is required for the procedure.

To calibrate the flow of gas through the T700 calibrator's optional photometer bench.

1. Turn OFF the T700 Dynamic Dilution Calibrator.
2. Attach the flow meter directly to the EXHAUST port of the T700 calibrator.
3. Turn the T700 Dynamic Dilution Calibrator ON.
4. Perform the following steps:



8.4. CALIBRATING THE O_3 GENERATOR

8.4.1. SETUP FOR VERIFICATION AND CALIBRATION THE O_3 GENERATOR

NOTE

An external reference photometer is required for the procedure.

8.4.1.1. Setup Using Direct Connections

Figure 8-5 shows the reference photometer connected directly to the fixtures on the back of the T700 Calibrator.

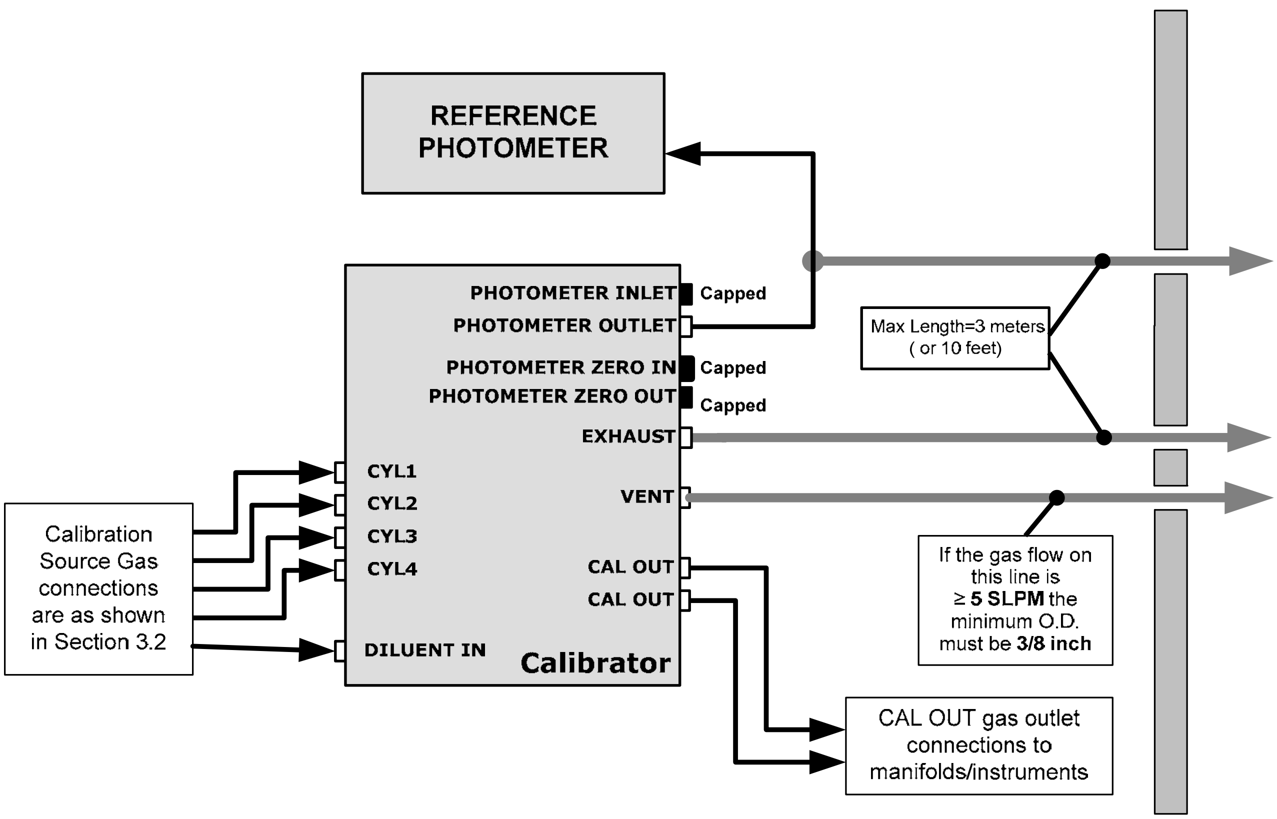
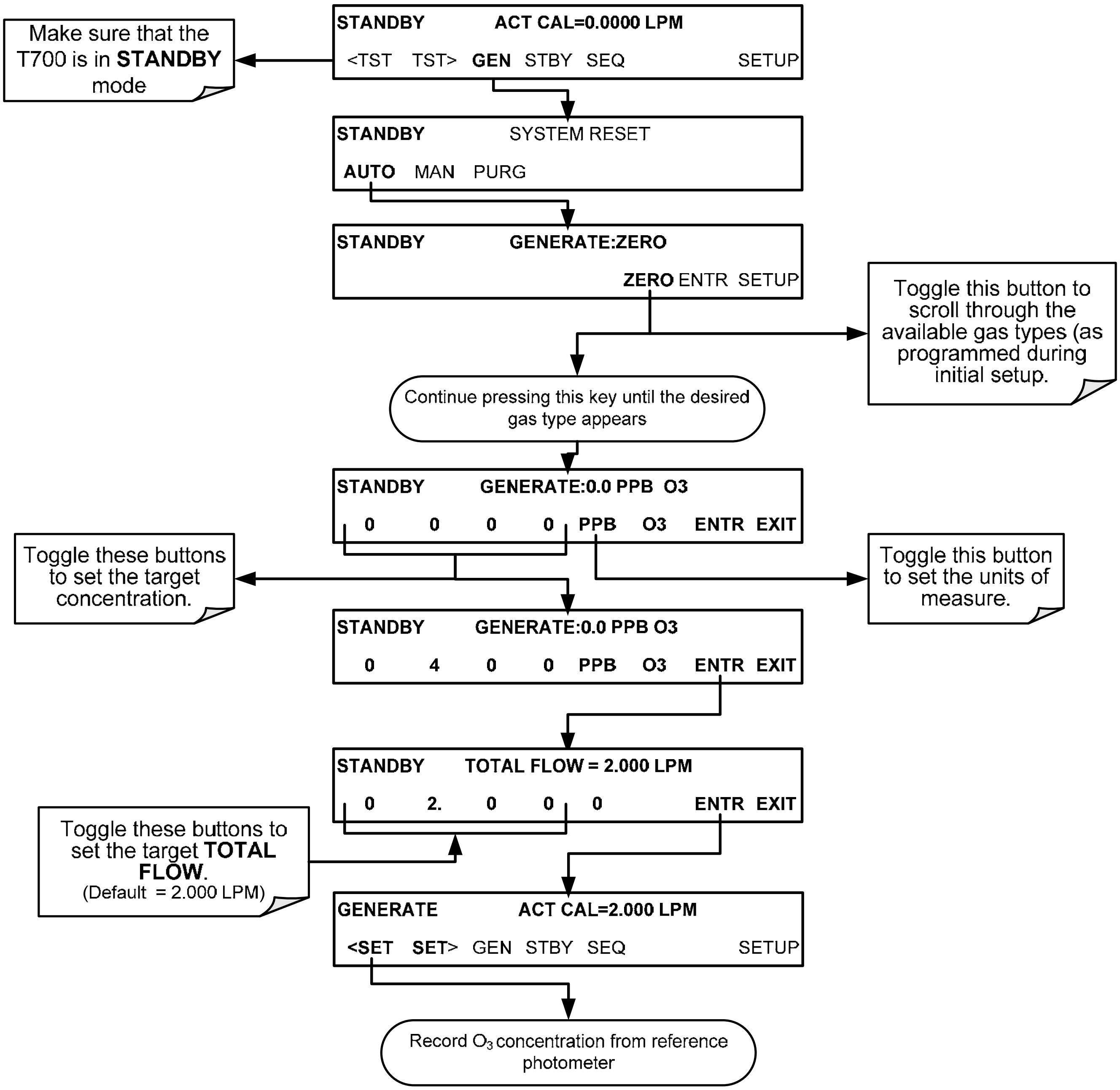


Figure 8-5: O_3 Generator Calibration Setup – Direct Connections

8.4.2. VERIFYING O_3 GENERATOR PERFORMANCE

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



NOTE

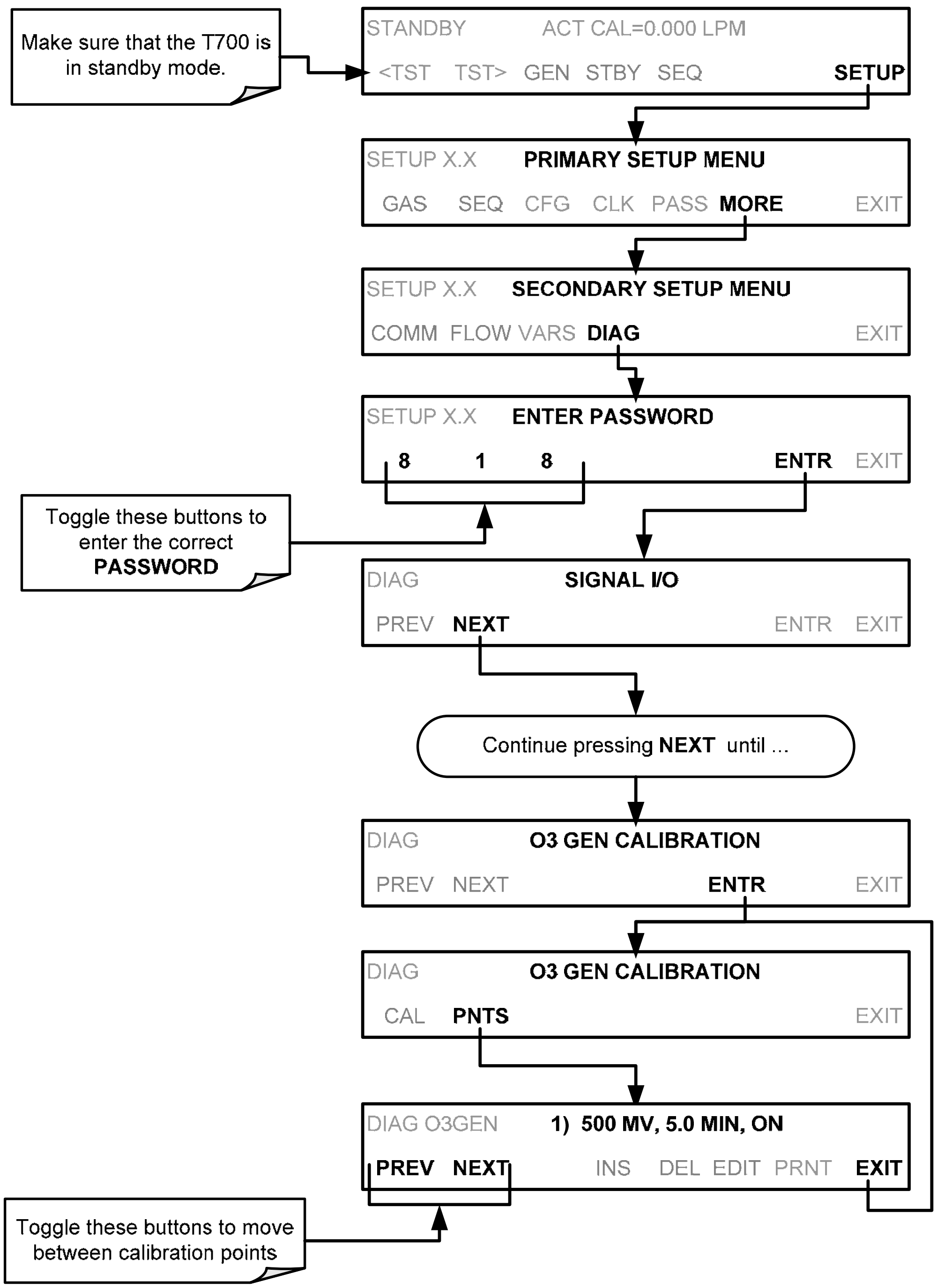
The readings recorded from the T700's ACT test function and the reference photometer should be within 1% of each other.

8.4.3. O_3 GENERATOR CALIBRATION PROCEDURE

The T700 calibrator's software includes a routine for automatically calibration the O_3 generator. A table of drive voltages stored in the T700's memory is the basis for this calibration. For each point included in the table used by the T700 to calibrate the optional O_3 generator the user can set a drive voltage and a dwell time for that point. Each point can also be individually turned OFF or ON.

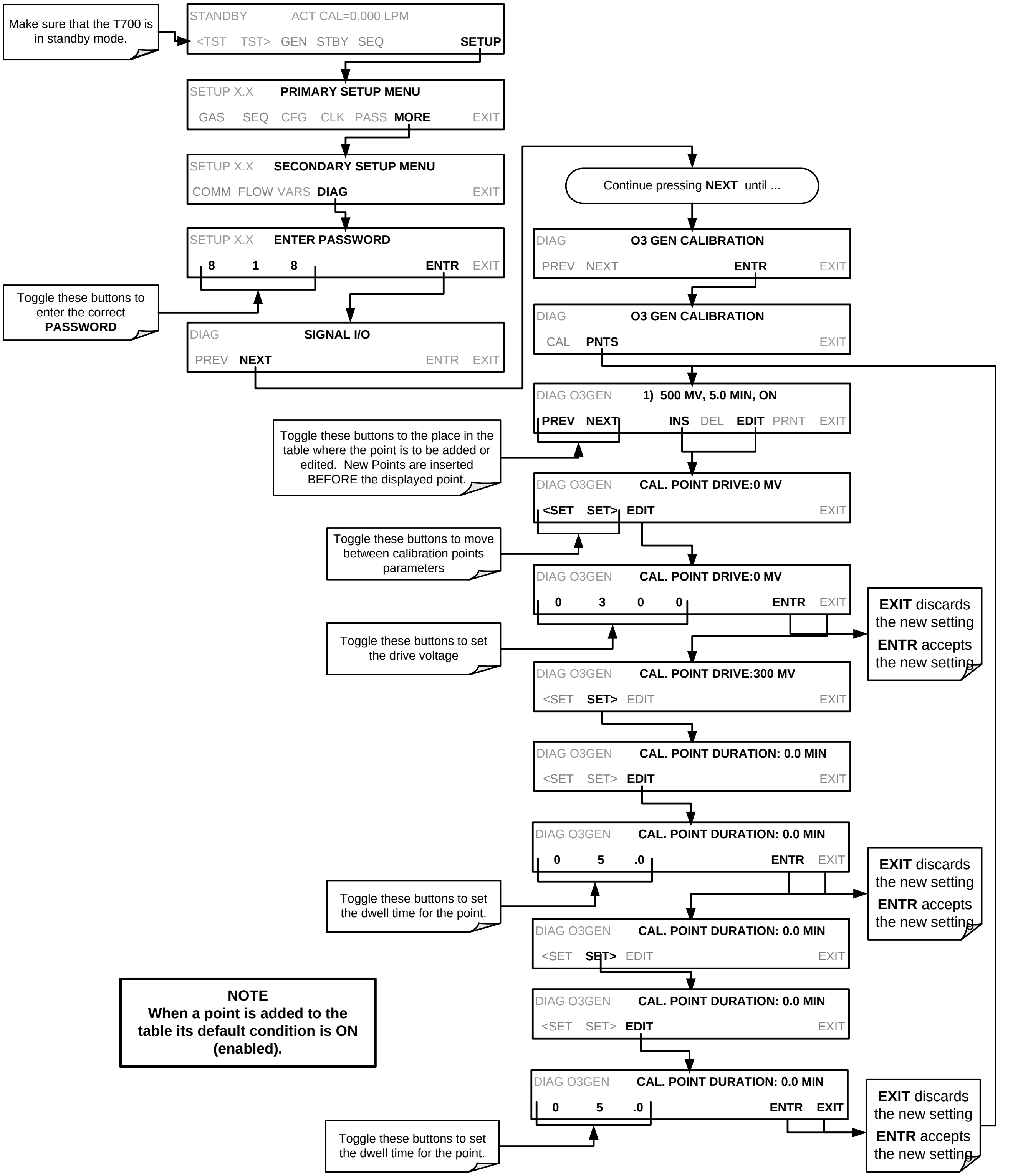
8.4.3.1. Viewing O_3 Generator Calibration Points

To view these calibration points, press:



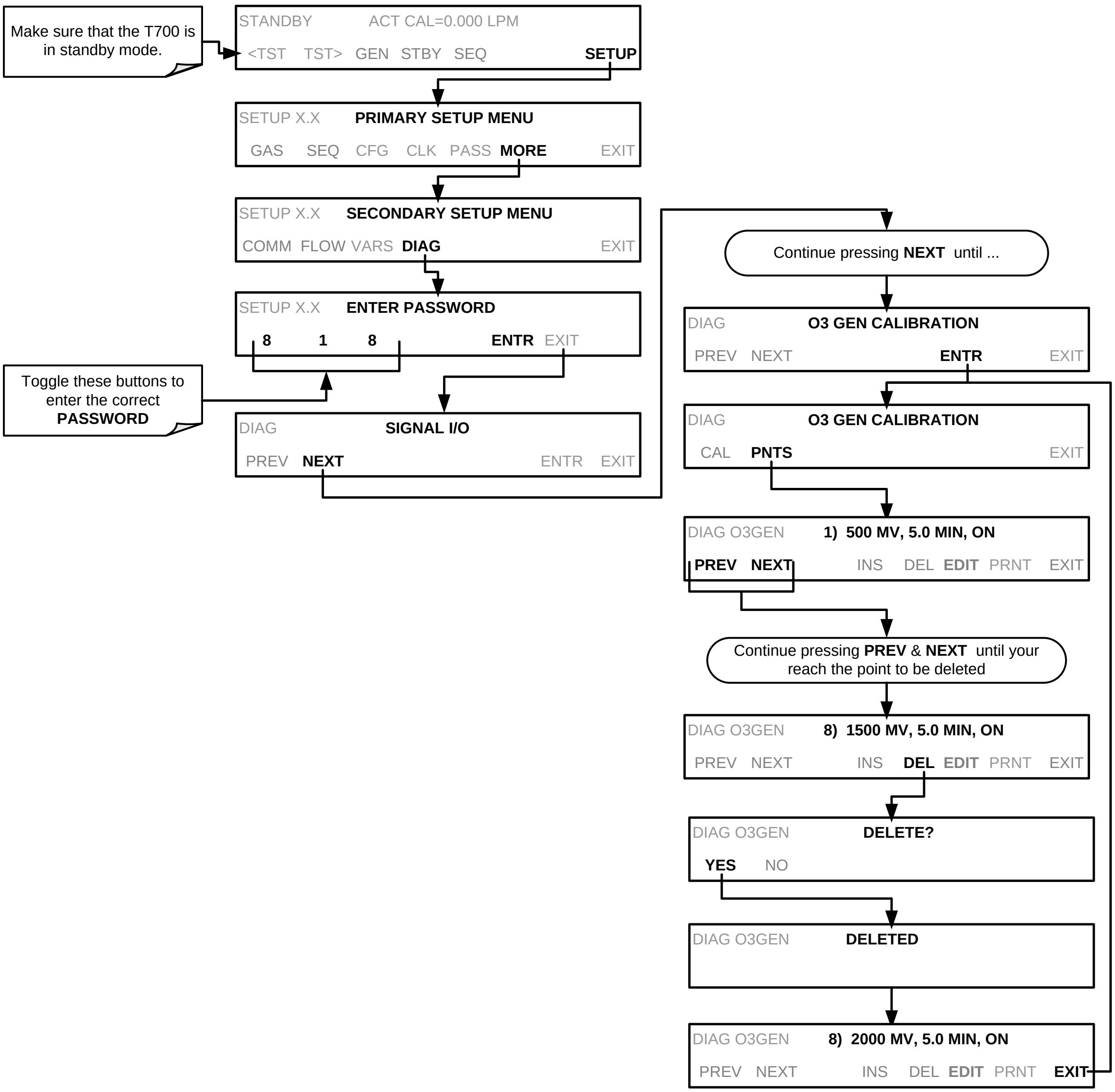
8.4.3.2. Adding or Editing O_3 Generator Calibration Points

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



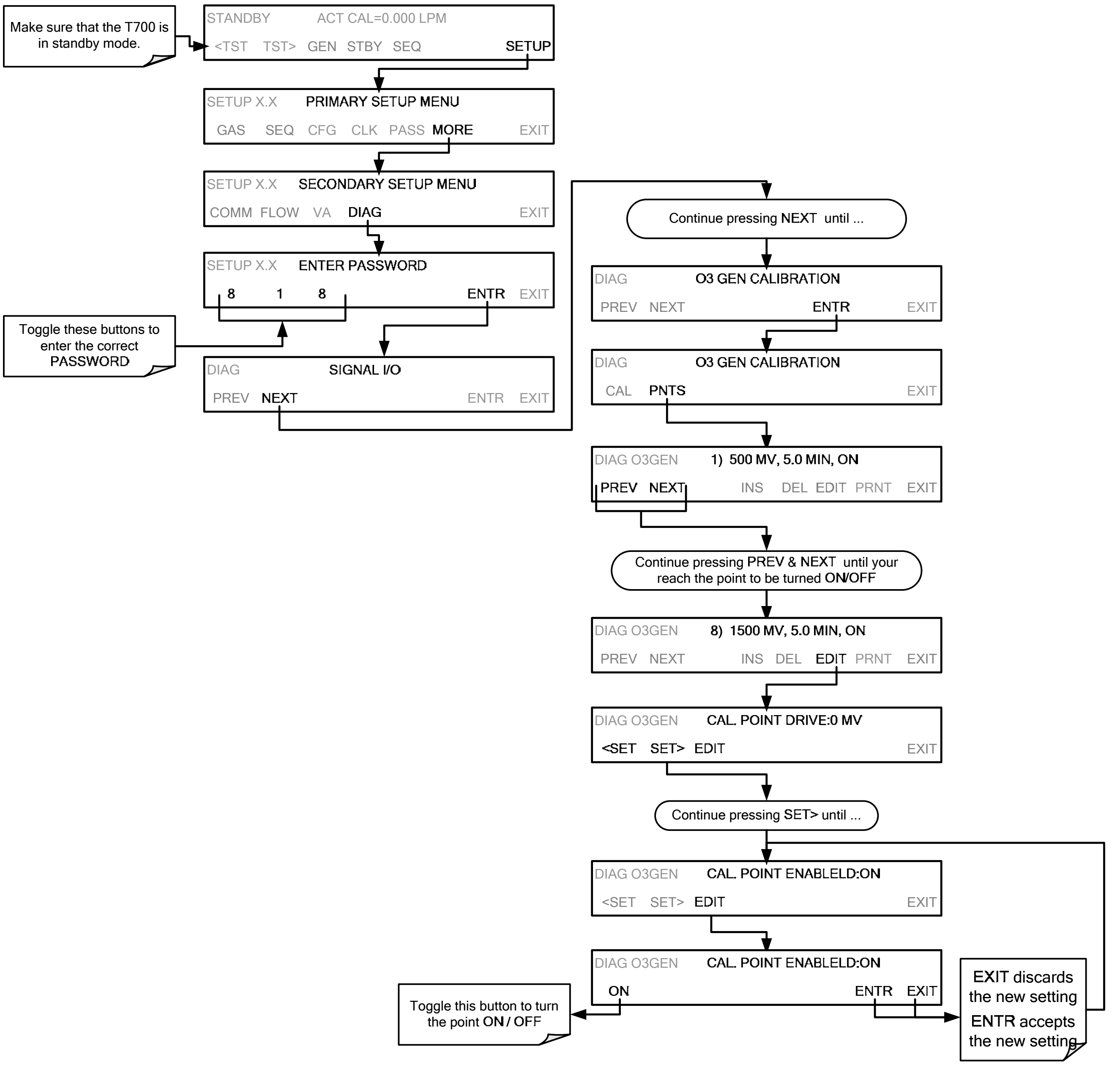
8.4.3.3. Deleting O_3 Generator Calibration Points

To delete an existing calibration point, press:



8.4.3.4. Turning O_3 Generator Calibration Points ON / OFF

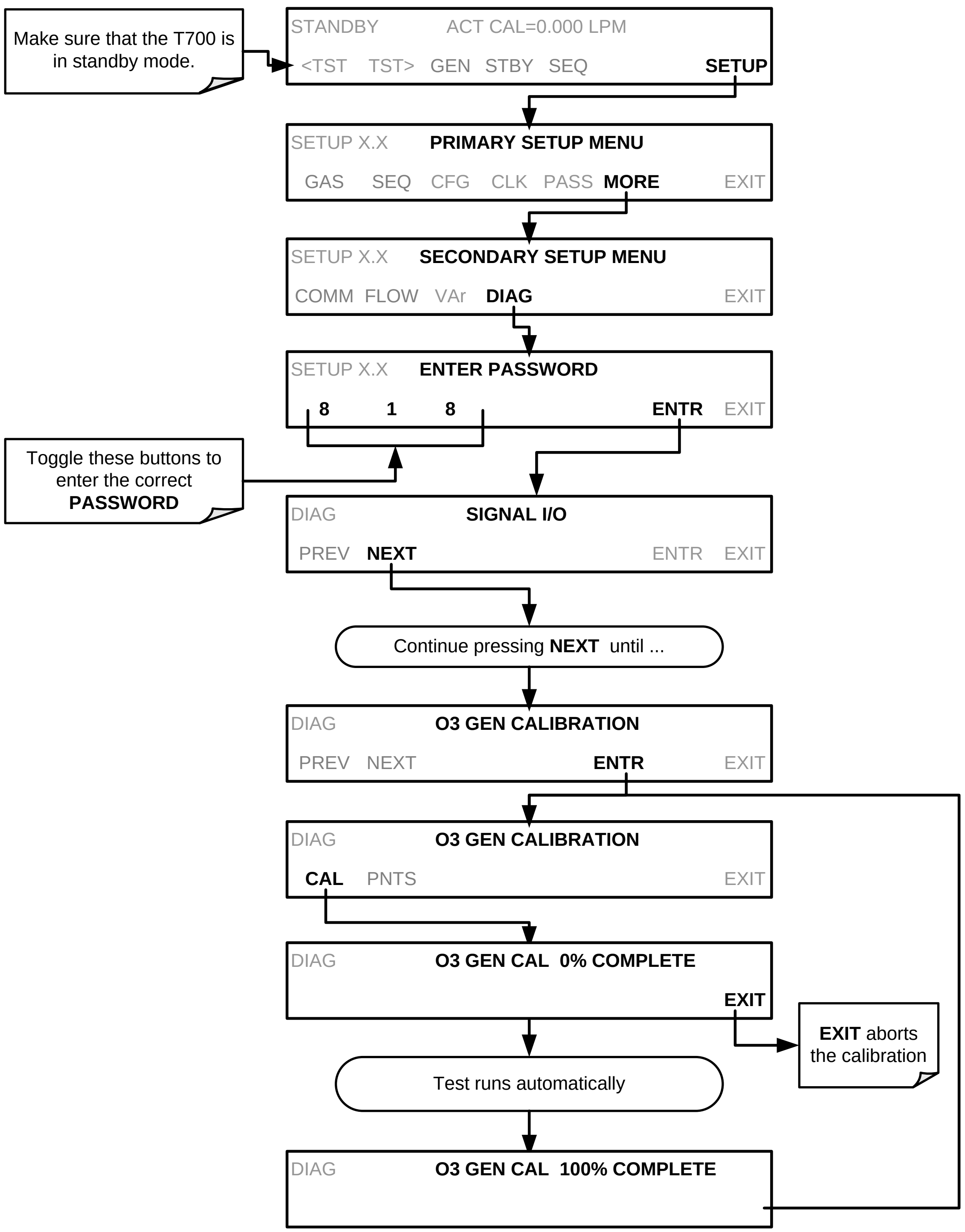
To enable or disable an existing calibration point, press:



8.4.3.5. Performing an Automatic Calibration of the Optional O_3 Generator

> **NOTE**
>
> **This procedure requires that the T700 calibrator have an optional photometer installed.**

To run the automatic O_3 generator calibration program, press:



8.5. T700 GAS PRESSURE SENSOR CALIBRATION

NOTE

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

The T700 Dynamic Dilution Calibrator has several sensors that monitor the pressure of the gases flowing through the instrument. The data collected by these sensors is 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 8-2: T700 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.

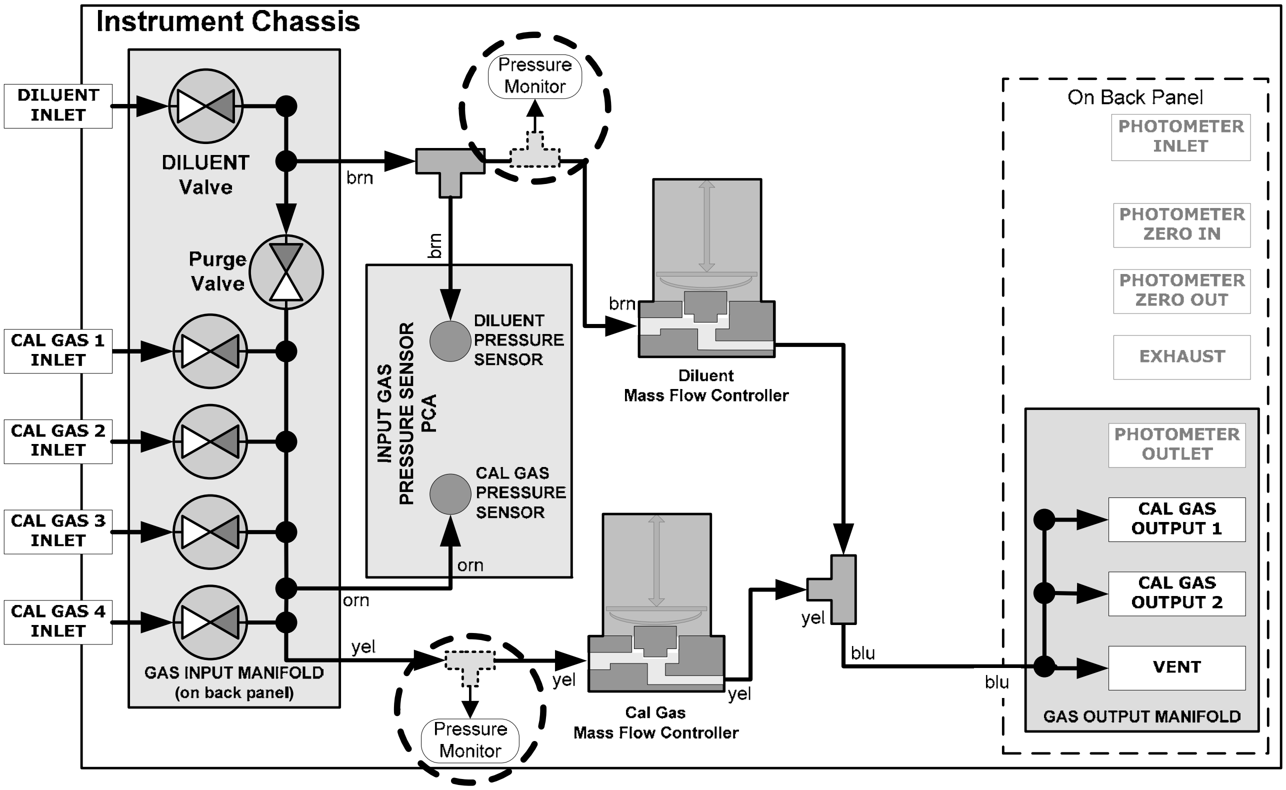


Figure 8-6: Pressure Monitor Points – T700 – Basic Unit

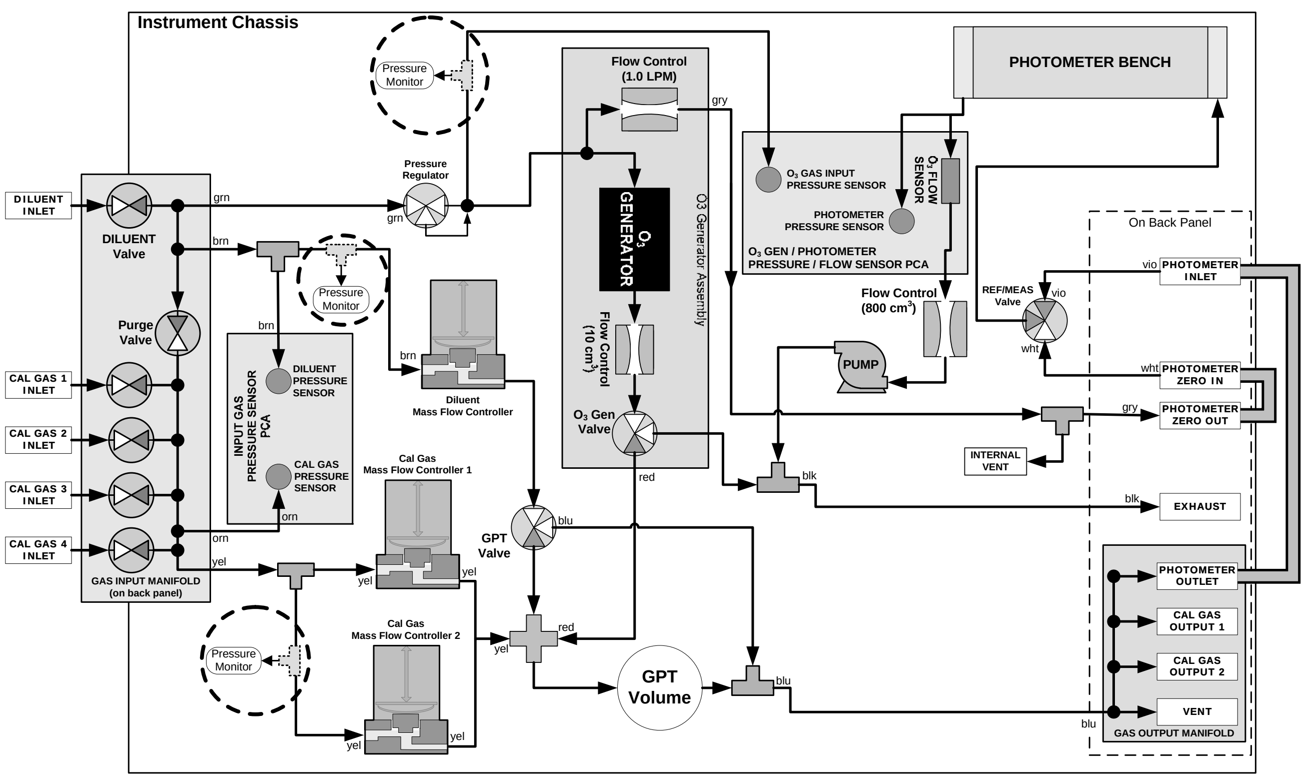
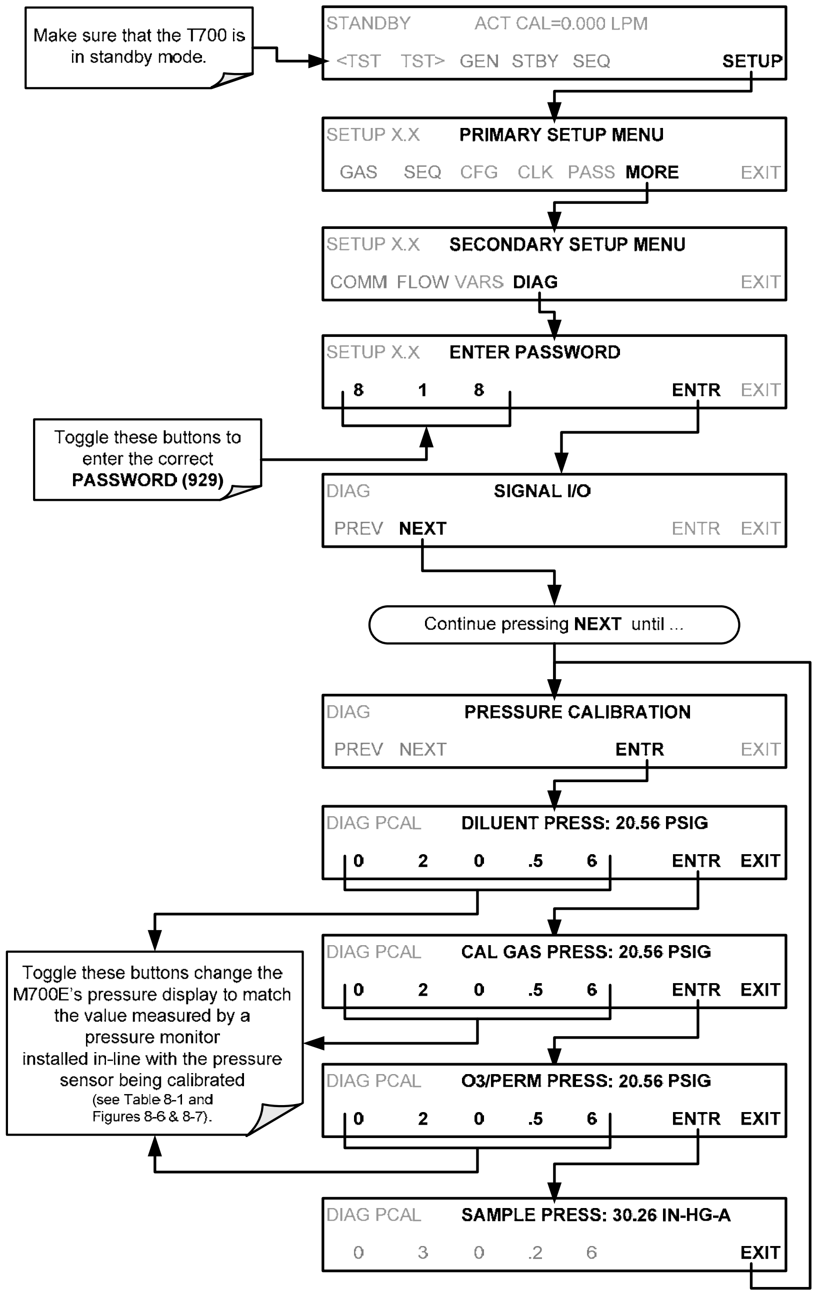


Figure 8-7: Pressure Monitor Points – T700 with O_3 Options and Multiple Cal MFC's Installed

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

1. Turn off the calibrator and open the top cover.
2. For the sensor being calibrated, insert a “T” pneumatic connector at the location described in Table 8-2 and shown in Figure 8-6 and Figure 8-7.
3. Turn on the calibrator and perform the following steps:

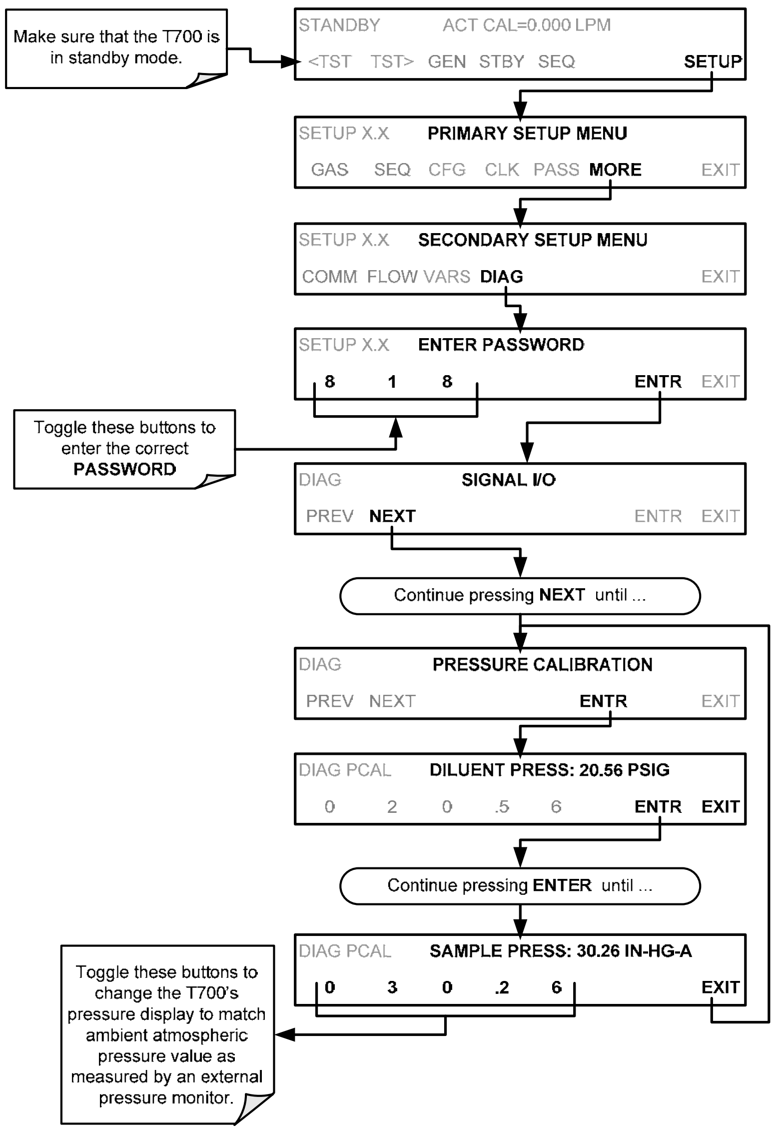


4. Turn OFF the T700.
5. Remove the pressure monitor.
6. Restore the pneumatic lines to their proper connections.
7. Close the calibrator’s cover.

8.5.1.2. 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 top cover.
2. Disconnect power to the photometer's internal pump.
3. Measure the ambient atmospheric pressure of T700's location in In-Hg-A.
4. Turn on the calibrator and perform the following steps:



5. Turn OFF the T700.
6. Reconnect the internal pump.
7. Close the calibrator's cover.

PART III
–
TECHNICAL INFORMATION

9. THEORY OF OPERATION

9.1. BASIC PRINCIPLES OF DYNAMIC DILUTION CALIBRATION

The T700 Dynamic Dilution Calibrator generates calibration gas mixtures by mixing bottled source gases of known concentrations with a diluent gas (zero air). Using several Mass Flow Controllers (MFC's) the T700 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 gasses 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 9-1

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

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 9-2a

$$\textbf{TOTALFLOW} = GAS_{flow} + Diluent_{flow}$$

WHERE:

GAS_{flow} = source gas flow rate

$Diluent_{flow}$ = zero air flow rate

For instrument with multiple source gas MFC total Flow is:

Equation 9-2b

$$\textbf{TOTALFLOW} = GAS_{flow\ MFC1} + GAS_{flow\ MFC2} \ldots + GAS_{flow\ MFCn} + Diluent_{flow\ rate}$$

This dilution process is dynamic. The T700'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 MFC's in real time so the flow rate control can be constantly adjusted to maintain a stable output concentration.

The T700 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 T700, it will create an exact output concentration of any of the gases in the bottle.

9.1.1. 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 T700 calibrator that allows the instrument to be use to create calibration mixtures that include O_3.

This ability to generate O_3 internally also allows the T700 Dynamic Dilution 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 9-3

$$NO + O_3 \quad \rightarrow NO_2 + O_2 + hv_{(light)}$$

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:

e) The amount of O_3 used in the mixture is known.

f) The amount of NO used in the mixture is **AT LEAST** 10% greater than the amount O_3 in the mixture.

g) The volume of the mixing chamber is known.

h) 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 T700 will be equal to (at a 1:1 ratio) to the amount of O_3 added.

Since:

- The O_3 flow rate of the T700'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 T700's memory and target concentration for the O_3 generator are entered into the calibrator's software, the T700 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 9-4

$$DIL_{flow} = Totalflow - NOGAS_{flow} - O_{3flow}$$

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 MFC's)

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 T700 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.

9.2. PNEUMATIC OPERATION

The T700 calibrator pneumatic system consists of the precision dilution system and valve manifold consisting of four gas port valves and one diluent air valve. When bottles of source gas containing different, gases are connected to the four source-gas inlet-ports, these valves are used to select the gas type to be used by opening and closing off gas flow from the various bottles upstream of the MFC's.

NOTE

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. Exceeding 35 PSI may cause leakage that could cause unwanted gases to be included in the calibration mixture.

By closing all of the four source gas input valves so that only zero air is allowed into the calibrator, the entire pneumatic system can be purges with zero air without having to manipulate the MFC's.

For instrument in which the O_3 generator and GPT pneumatics are installed, a glass volume, carefully selected per the U.S. E.P.A. guidelines is used to optimize NO_2 creation.

See Figure 3-7 and Figure 3-8 for descriptions of the internal pneumatics for the T700 calibrator.

9.2.1. GAS FLOW CONTROL

The precision of gas flow through the T700 Dynamic Dilution Calibrator is centrally critical to its ability to mix calibration gases accurately. This control is established in several ways.

9.2.1.1. Diluent and Source Gas Flow Control

Diluent and source gas flow in the T700 calibrator is a directly and dynamically controlled buy using highly accurate Mass Flow Controller. These MFC's 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 MFC's 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 MFC's 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 and increase of temperature in the capillary tube and produces a mVDC output signal proportional to that change that is proportional to the rate of flow through the MFC's 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 T700'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 MFC's 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 dependant 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 flowmeter is calibrated directly in molar mass units for known gases (see Section **Error! Reference source not found.**). 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 flowmeter is capable of measuring a wide variety of gases.

9.2.1.2. 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 MFC, under direction of the CPU, gas flow through is controlled n on dynamically 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.

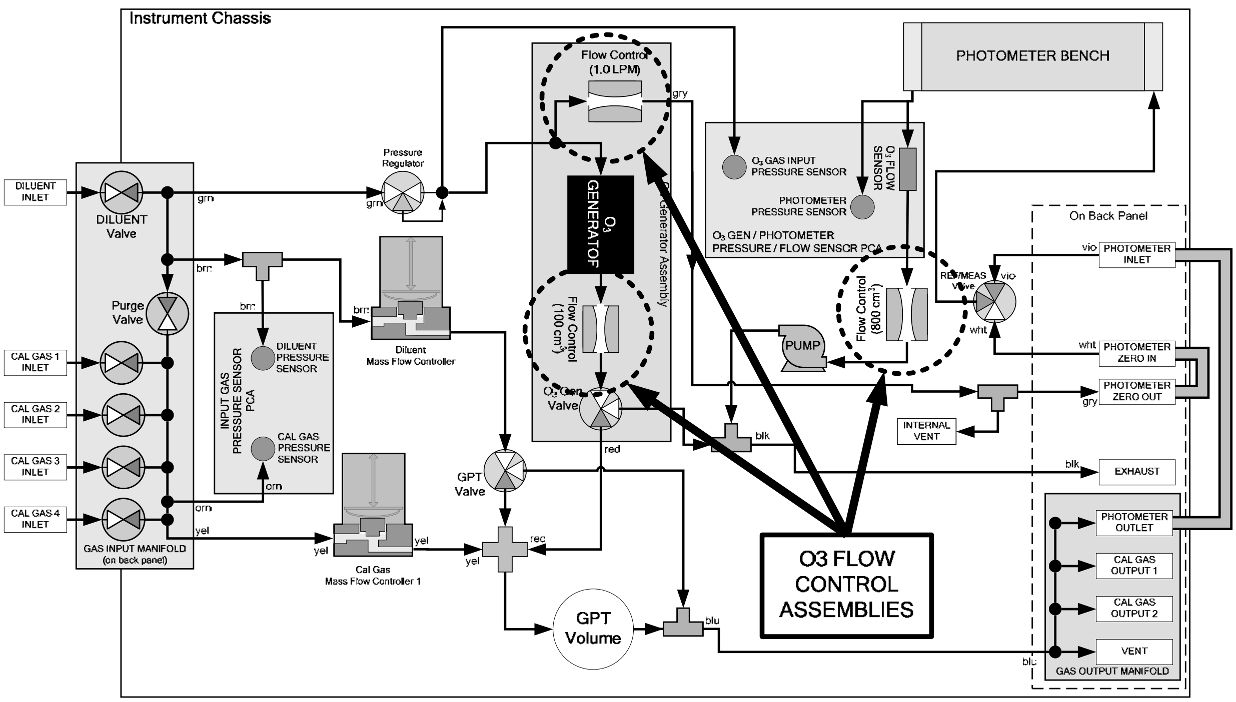


Figure 9-1: Location of Gas Flow Control Assemblies for T700's with O_3 Options Installed

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.

9.2.1.3. 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.

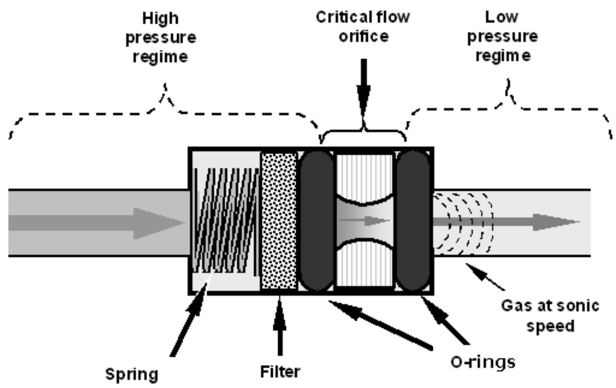


Figure 9-2: Flow Control Assembly & Critical Flow Orifice

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.

9.2.2. INTERNAL GAS PRESSURE SENSORS

The T700 includes a single pressure regulator. Depending upon how many and which options are installed in the T700 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 MFC's 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.

9.3. ELECTRONIC OPERATION

9.3.1. OVERVIEW

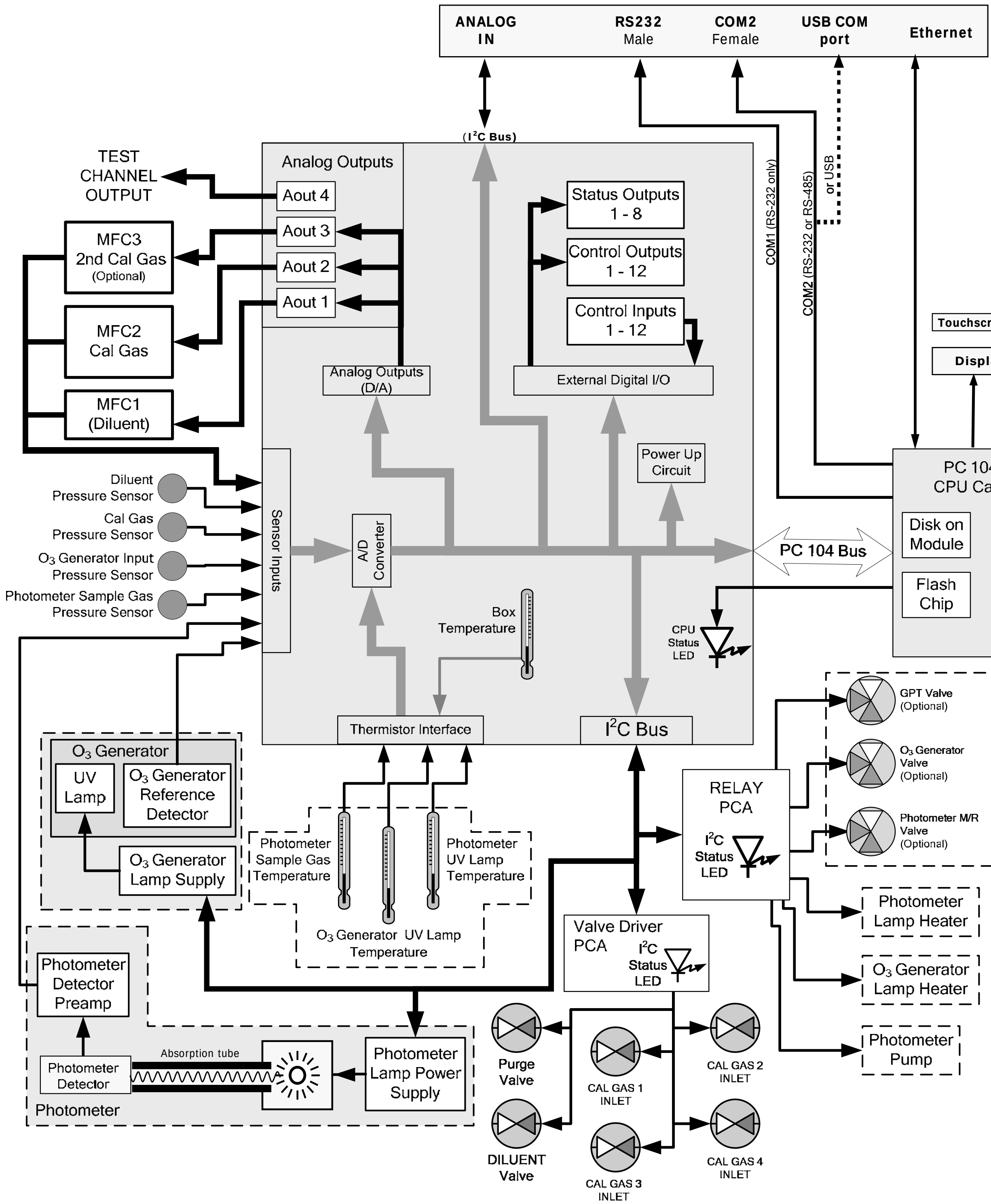


Figure 9-3: T700 Electronic Block Diagram

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 rear 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 T700 (e.g. flow data from the MFC's, 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 front panel display.

The CPU communicates with the user and the outside world in a variety of manners:

- Through the calibrator's front panel 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.

9.3.2. CPU

The unit's CPU card (Figure 9-4) is installed on the motherboard located inside the rear 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:

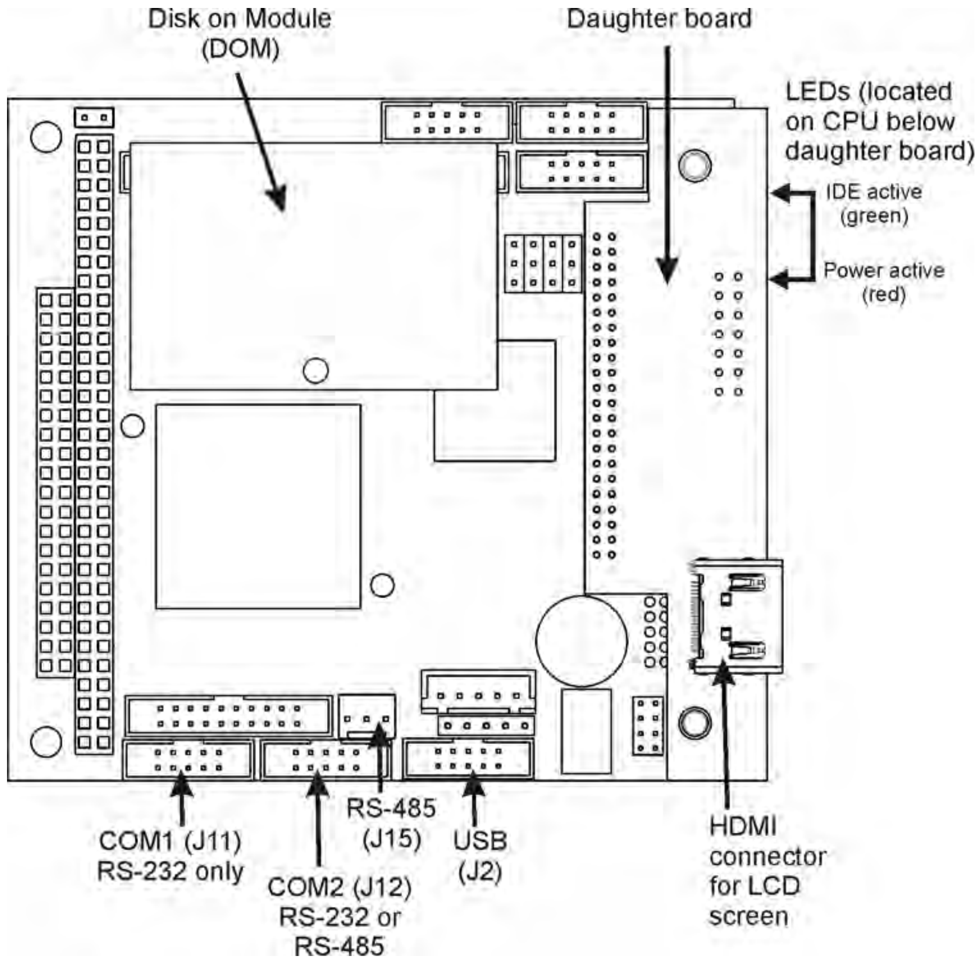


Figure 9-4: T700 CPU Board Annotated

The CPU includes two types of non-volatile data storage: an embedded 2MB flash chip and a Disk on Module (DOM).

9.3.2.1. 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.

9.3.2.2. Flash Chip

This non-volatile memory includes 2MB of space and is used to store calibration data and to store a backup of the calibrator's configuration as created during final checkout at the factory. Separating these data onto a less frequently accessed chip significantly decreases the chance of those key data getting corrupted.

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.

9.3.3. 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.

Generally, the relay PCA is located in the right-rear quadrant of the calibrator and is mounted vertically on the back of the same bracket as the instrument's DC power supplies, however the exact location of the relay PCA may differ from model to model (see Figure 3-5 or Figure 3-6).

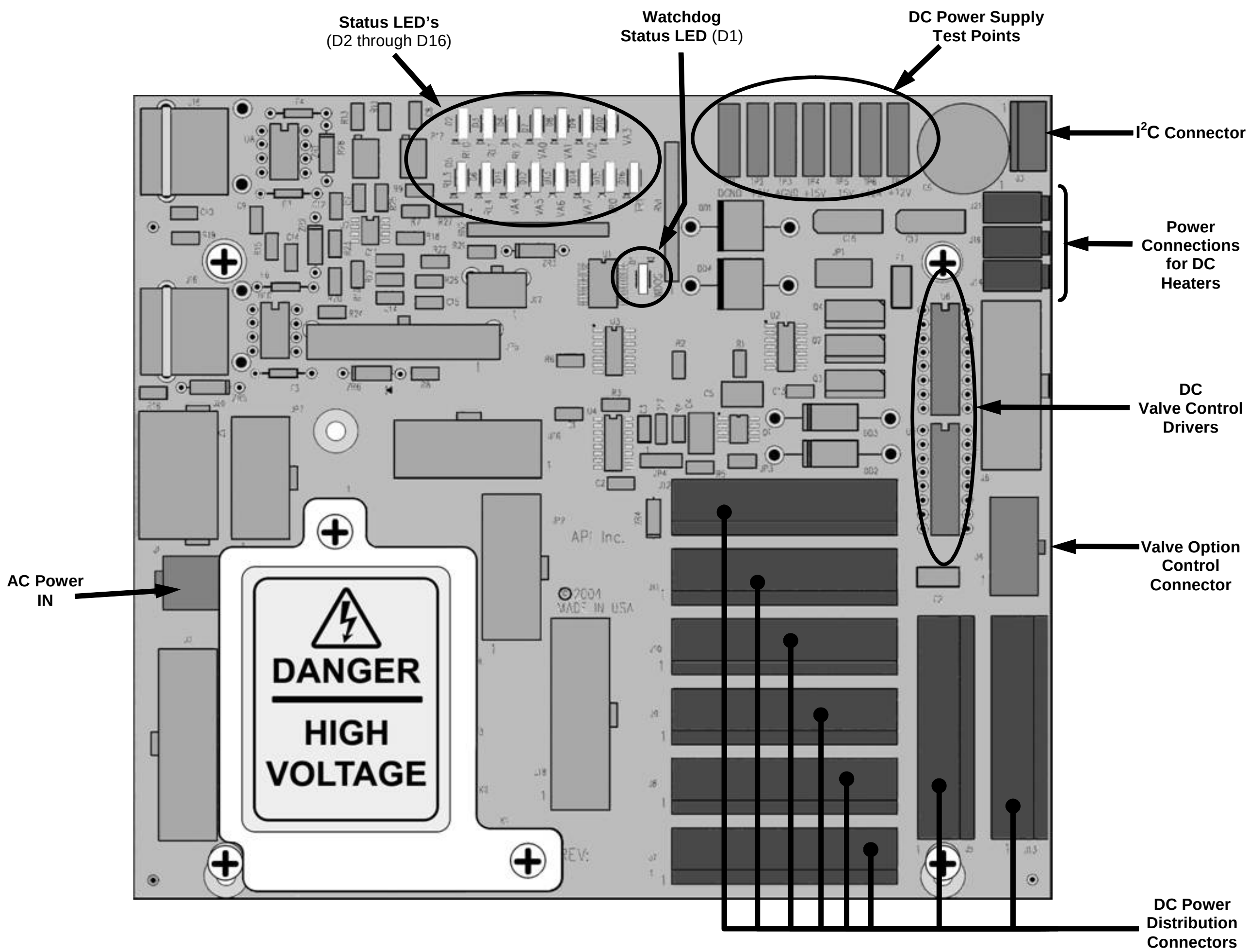
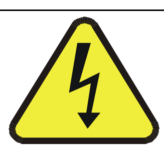


Figure 9-5: Relay PCA

This is the base version of the Relay PCA. It does not include the AC relays and is used in instruments where there are no AC powered components requiring control. A plastic insulating safety shield covers the empty AC Relay sockets.



CAUTION

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

9.3.3.1. Valve Control

The relay PCA also hosts two valve driver chips, each of which can drive up four valves. In the T700, the relay PCA controls only those valves associated with the O_3 generator and photometer options. All valves related to source gas and diluent gas flow are controlled by a separate valve driver PCA (see Section 9.3.4).

9.3.3.2. Heater Control

The relay PCA controls the various DC heaters related to the O_3 generator and photometer options.

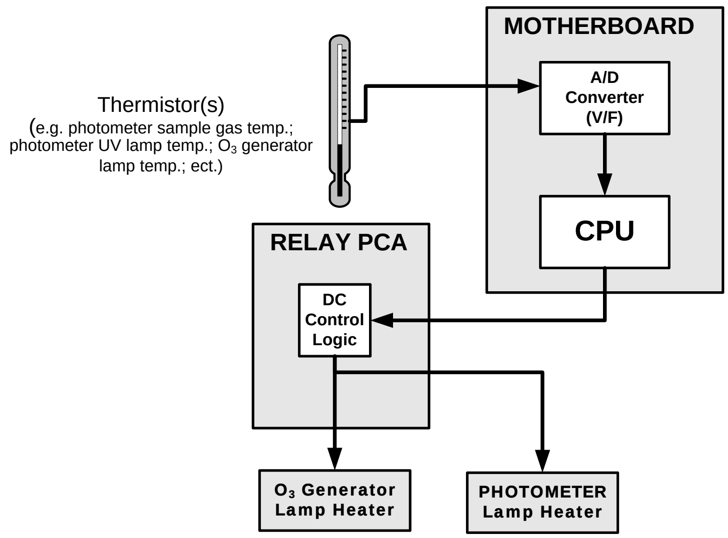


Figure 9-6: Heater Control Loop Block Diagram.

9.3.3.3. Relay PCA Status LEDs & Watch Dog Circuitry

Thirteen LEDs are located on the calibrator's relay PCA to indicate the status of the calibrator's heating zones and some of its valves as well as a general operating watchdog indicator.

Table 9-1 shows the status of these LEDs and their respective functionality.

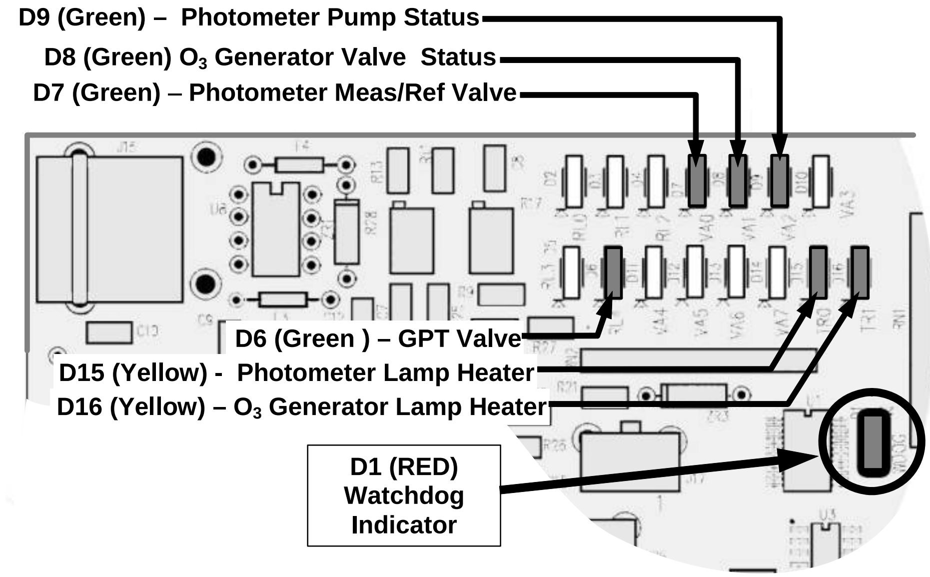


Figure 9-7: Status LED Locations – Relay PCA

Table 9-1: Relay PCA Status LEDs

LED	COLOR	DESCRIPTION	FUNCTION
D1	Red	Watchdog Circuit; I^2C bus operation.	Blinks when I^2C bus is operating properly
D2-6	SPARE		
D7[1]	Green	Photometer Meas/Ref Valve	When lit the valve open to REFERENCE gas path
D8[2]	Green	O_3 generator Valve status	When lit the valve open to O_3 generator gas path
D9	Green	Photometer Pump status	When lit the pump is turner on.
D6[1,2]	Yellow	GPT Valve status	When lit the valve open to GT Chamber
D10 - 14	SPARE		
D15[1]	Yellow	Photometer Heater Status	When lit the photometer UV lamp heater is on
D16[2]	Yellow	O_3 Generator Heater Status	When lit the O_3 generator UV lamp heater is on
[1] Only applies on calibrators with photometer options installed. [2] Only applies on calibrators with O_3 generator options installed.			

9.3.3.4. 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.

9.3.4. VALVE DRIVER PCA

The valves that operate the T700 calibrator's main source gas and diluent gas inputs are controlled by a PCA that is attached directly to the input valve manifold (see Figure 3-5 or Figure 3-6). Like the relay PCA, the valve driver PCA communicates with T700's CPU through the motherboard over the I^2C bus.

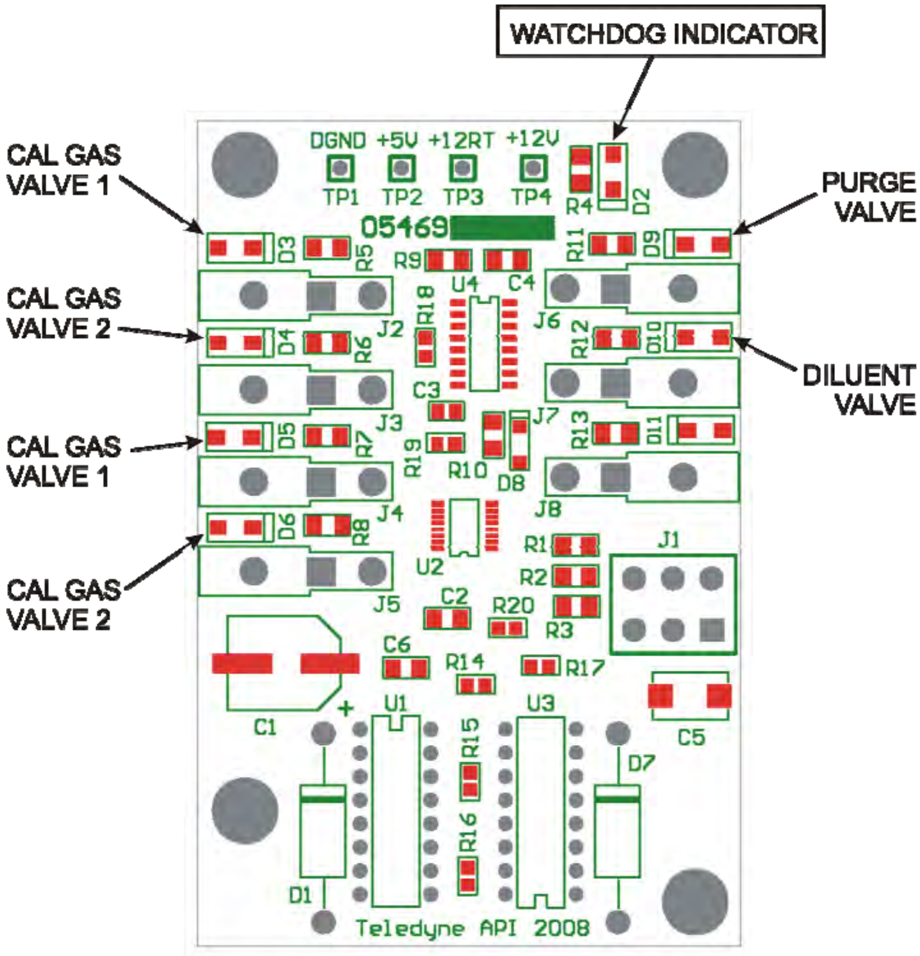


Figure 9-8: Status LED Locations – Valve Driver PCA

9.3.4.1. Valve Driver PCA Watchdog Indicator

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. Like the watchdog LED on the relay PCA, should this LED ever stay ON or OFF for 30 seconds if the CPU or I^2C bus has stopped functioning, this Watchdog Circuit automatically shuts all valves and turns off all heaters and lamps.

9.3.5. MOTHERBOARD

This is the largest electronic assembly in the calibrator and is mounted to the rear panel as the base for the CPU board and all I/O connectors. This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I^2C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

9.3.5.1. 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 coverts 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.

9.3.5.2. 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.

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

9.3.5.3. Thermistor Interface

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the calibrator.

9.3.5.4. Analog Outputs

The T700 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 6-13) and will output an analog VDC signal that rises and falls in relationship with the value of the chosen parameter.

9.3.5.5. 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 rear panel of the calibrator. These outputs convey on/off information about certain calibrator conditions such as **CONC VALID**. 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 6.5.2.8).

The **CONTROL** inputs can be initiated by applying 5V DC power from an external source such as a PLC or data logger (Section 6.5.1.5). Zero and span calibrations can be initiated by contact closures on the rear panel.

9.3.5.6. 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, optional analog input board and valve driver board circuitry.

9.3.5.7. 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.

9.3.6. INPUT GAS PRESSURE SENSOR PCA

This PCA, physically located to the just to the left of the MFC's, 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 front panel:

- **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.**

9.3.7. POWER SUPPLY AND CIRCUIT BREAKER

The T700 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.

NOTE

The T700 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.

CAUTION

Should the power circuit breaker trip correct the condition causing this situation before turning the calibrator back on.

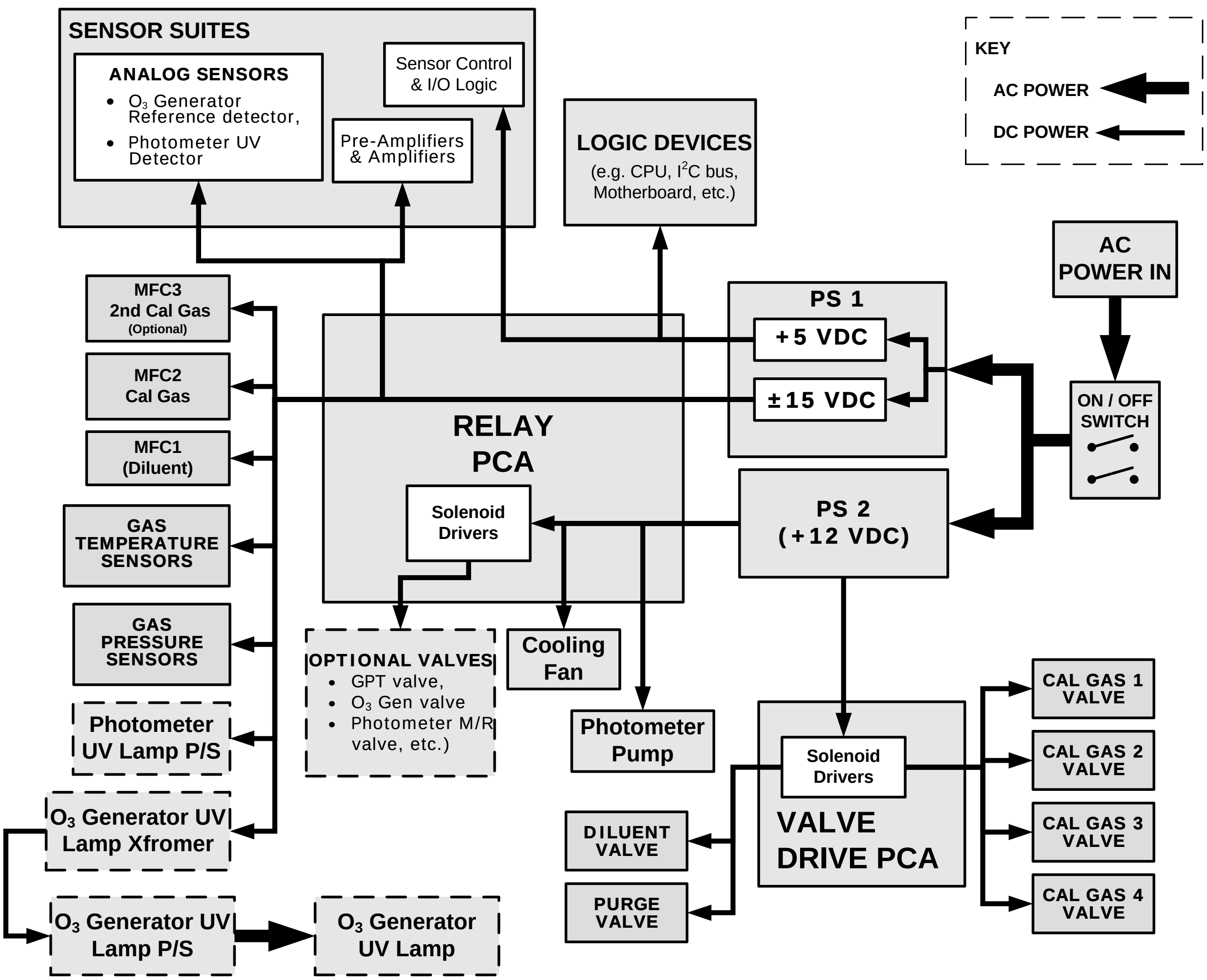


Figure 9-9: T700 Power Distribution Block diagram

9.4. FRONT PANEL TOUCHSCREEN/DISPLAY INTERFACE

The most commonly used method for communicating with the T700 Dynamic Dilution Calibrator is via the instrument's front panel LCD touchscreen display from where users can input data and receive information directly.

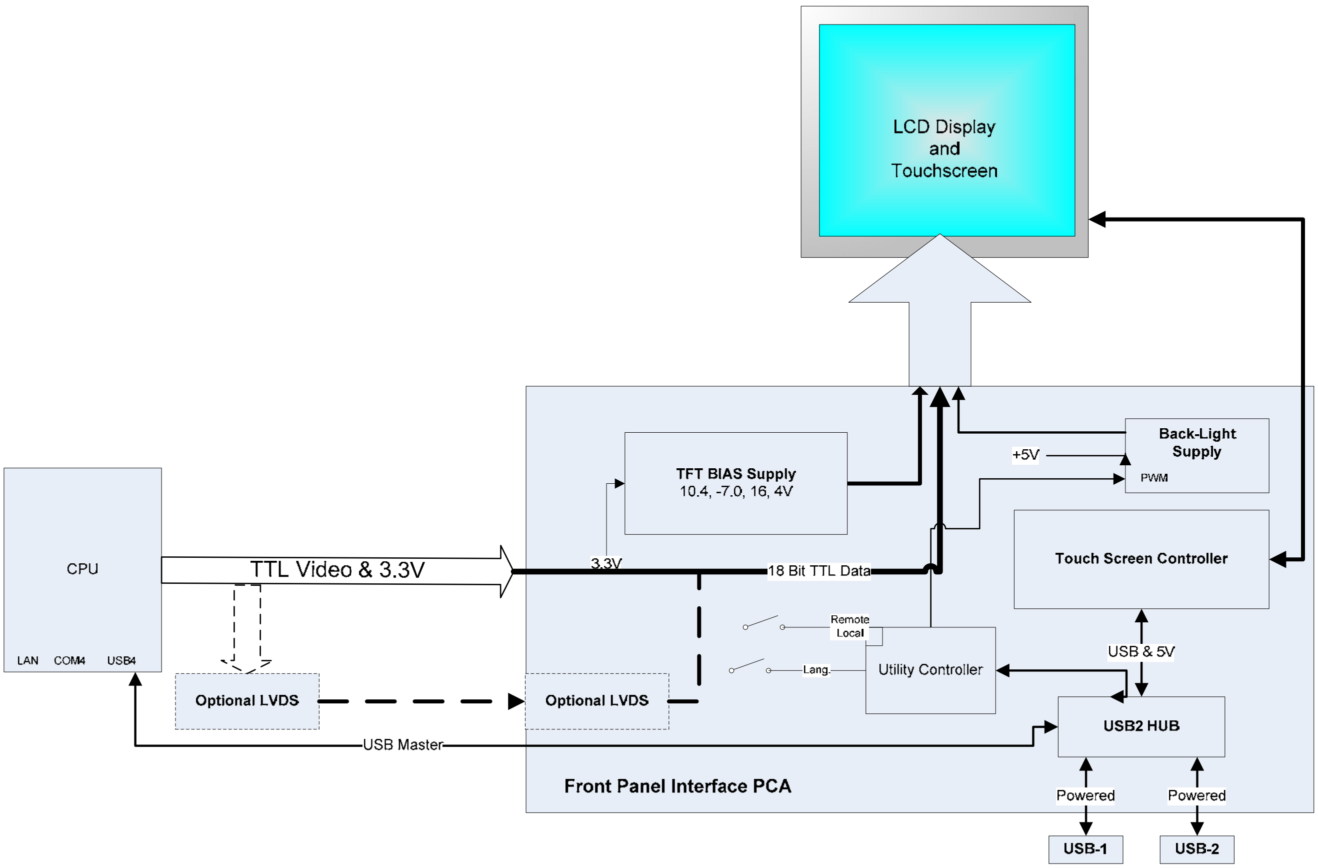


Figure 9-10: Front Panel Display Interface Block Diagram

The LCD display 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.

9.4.1.1. Front Panel Interface PCA

The front panel interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module
- a USB hub that is used for communications with the touchscreen controller and the two front panel USB device ports
- the circuitry for powering the display backlight

9.5. SOFTWARE OPERATION

The T700 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 9-11 shows a block diagram of this software functionality.

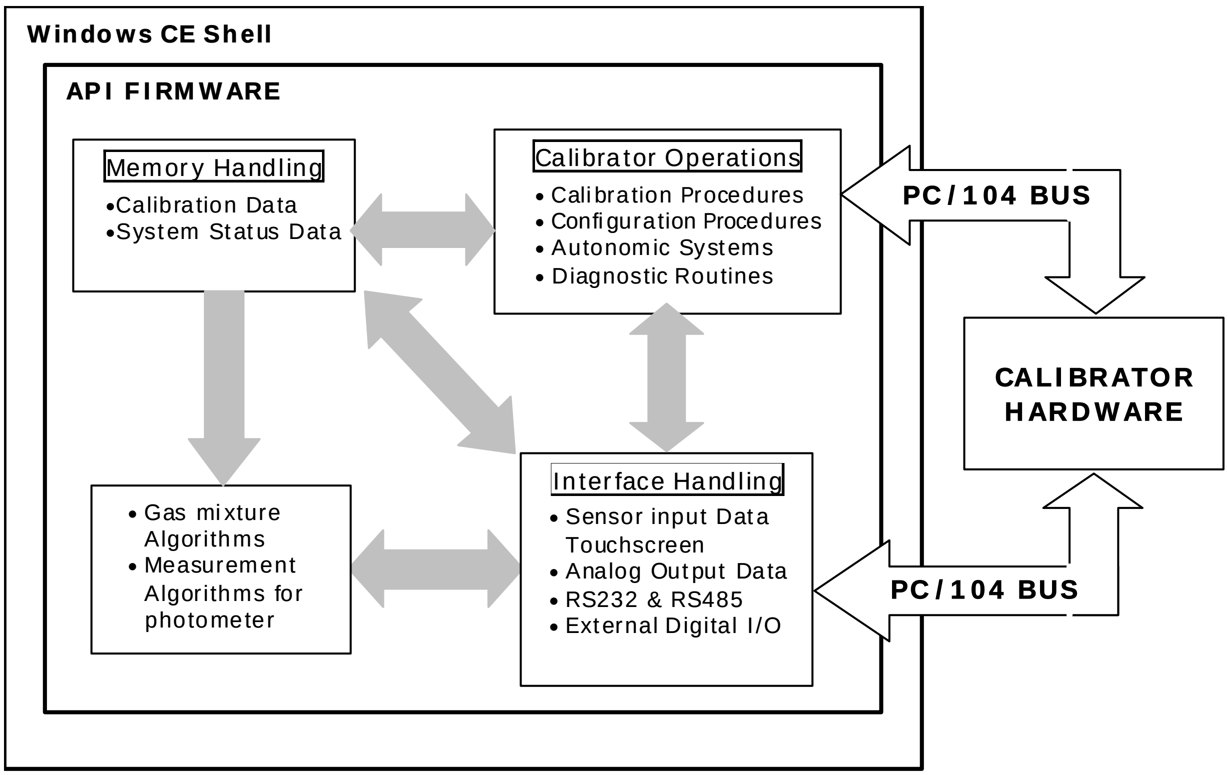


Figure 9-11: Schematic of Basic Software Operation

9.6. O_3 GENERATOR OPERATION

9.6.1. PRINCIPLE OF PHOTOLITIC 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 there fore 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).

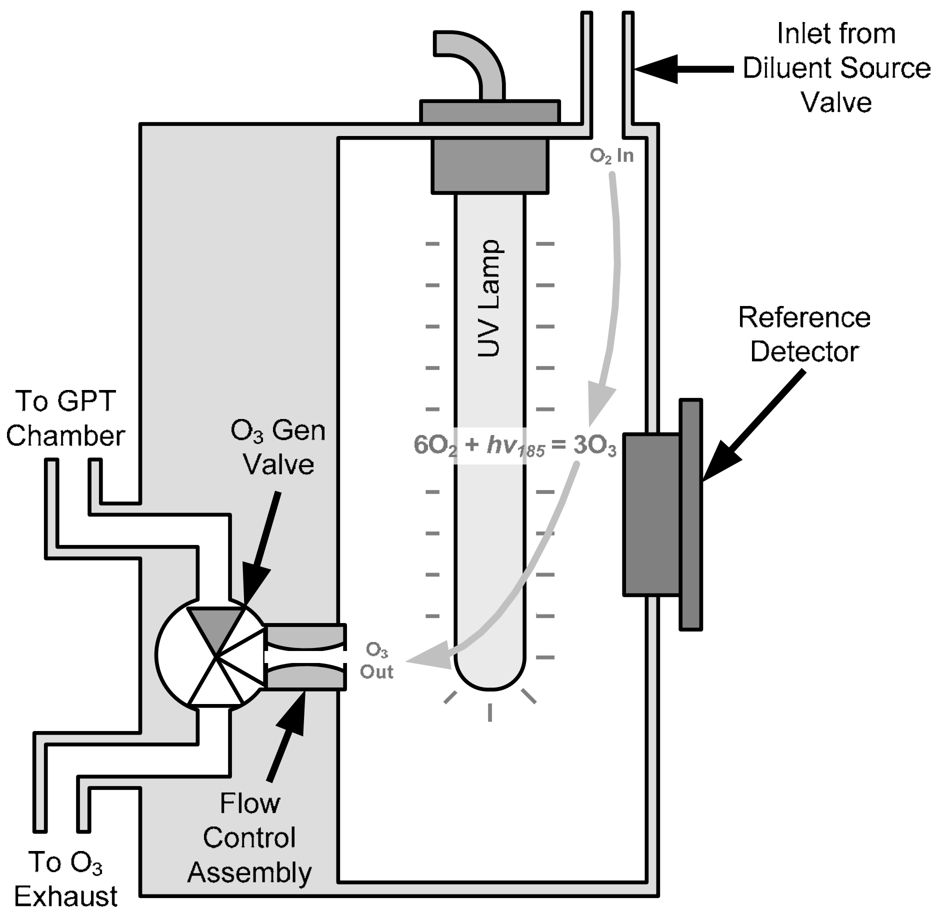


Figure 9-12: O_3 Generator Internal Pneumatics

9.6.2. O_3 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 back 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 is downstream from the generator chamber itself and directs the output of the generator to either the GPT mixing chamber or the exhaust vent at the back 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 required 2:1 pressure ration across the critical flow orifice of the flow control assembly (see Section 9.2.1.3).

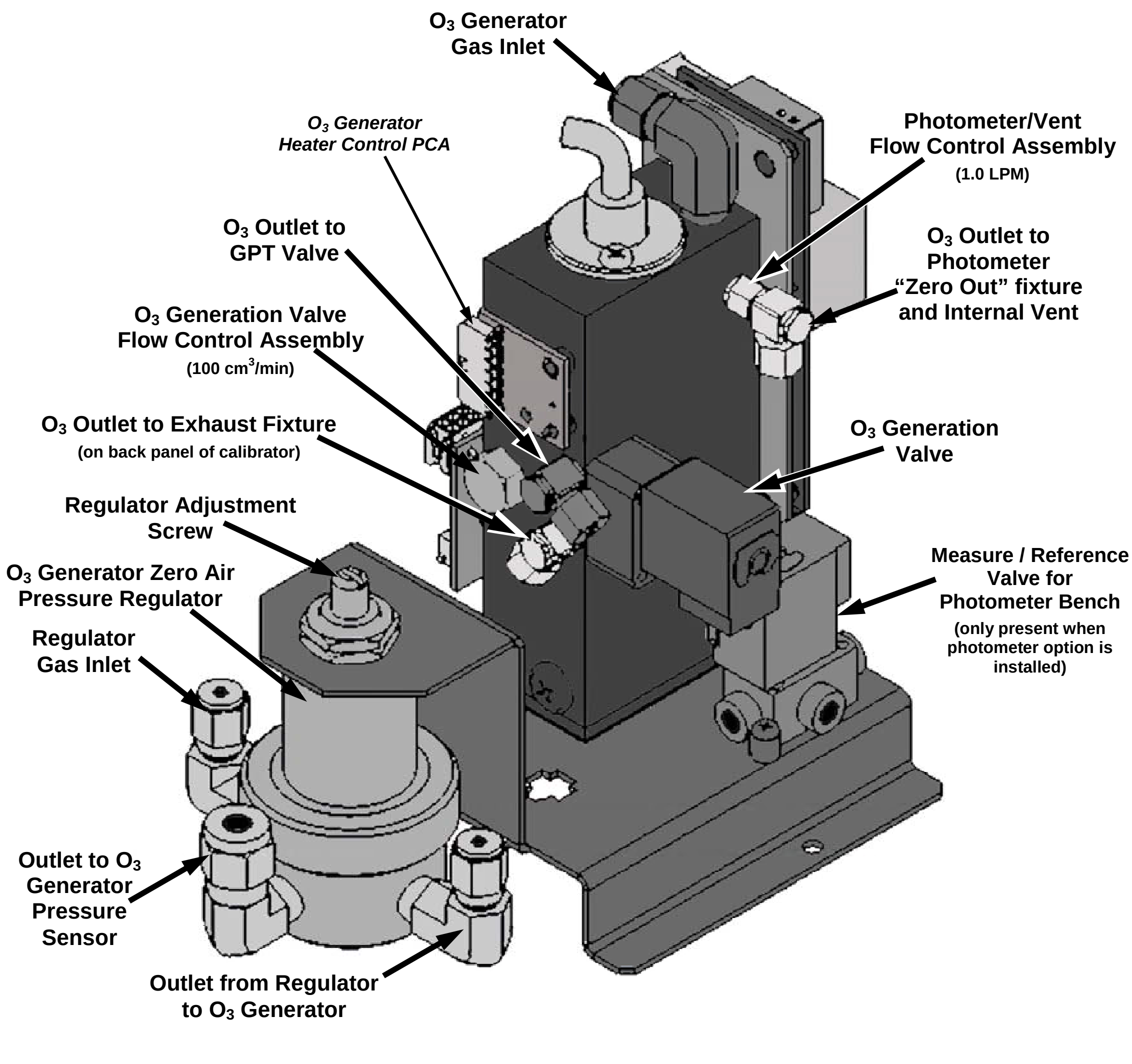


Figure 9-13: O_3 Generator Valve and Gas Fixture Locations

9.6.3. O_3 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 is sent by the motherboard to the calibrator's CPU and where required 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 calibrators I^2C bus.

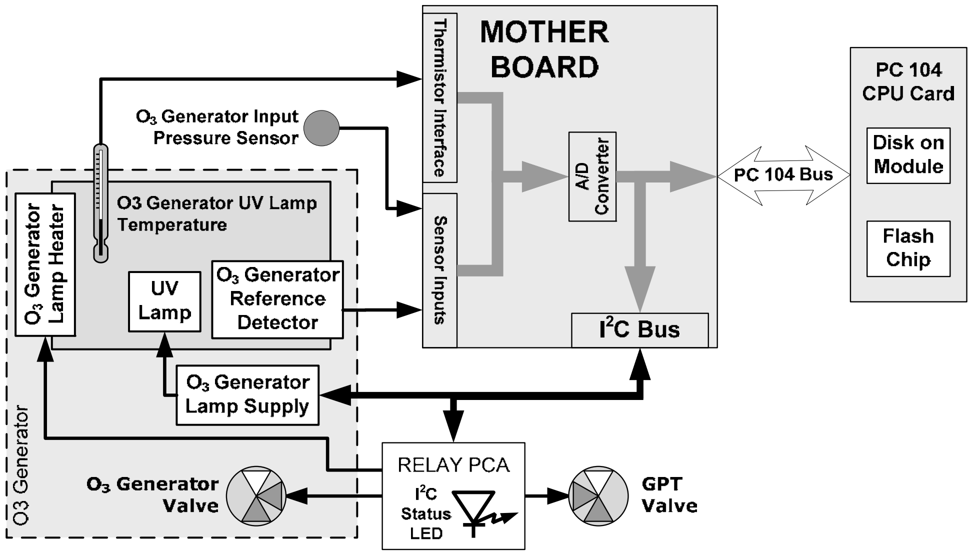


Figure 9-14: O_3 Generator – Electronic Block Diagram

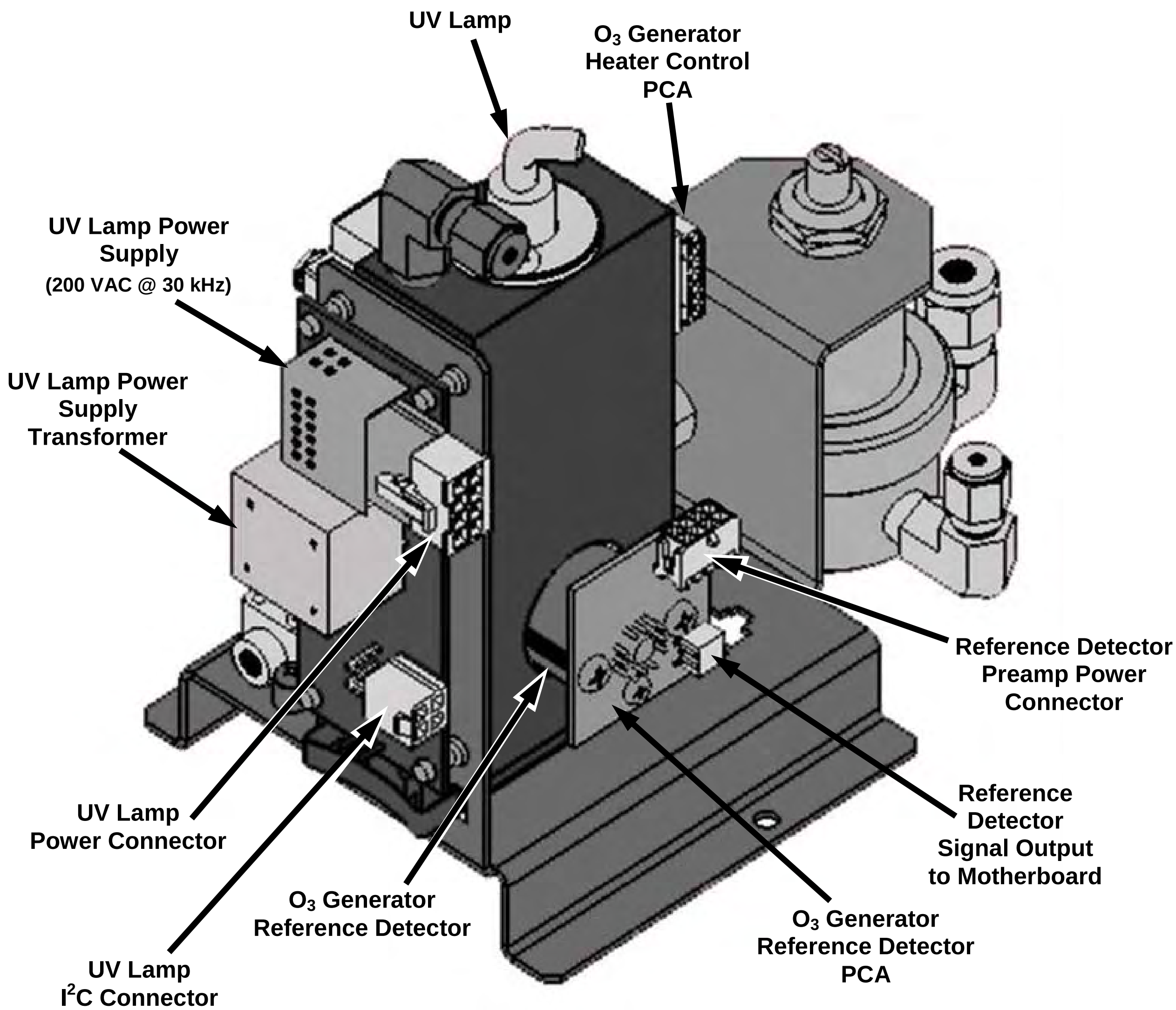


Figure 9-15: O_3 Generator Electronic Components Location

9.6.3.1. O_3 Generator Temperature Control

In order to operate at peak efficiency the UV lamp of the T700'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 9.3.3). The location of the thermistor and heater associated with the O_3 generator is shown in Figure 9-16:

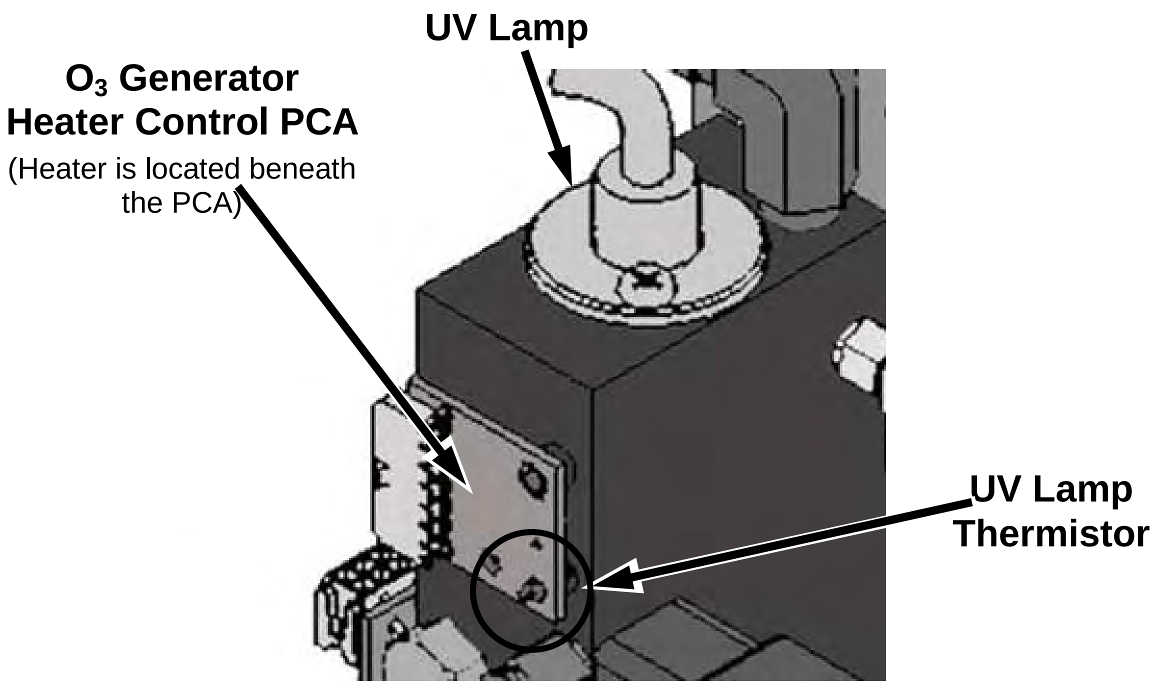


Figure 9-16: O_3 Generator Temperature Thermistor and DC Heater Locations

9.6.3.2. Pneumatic Sensor for the O_3 Generator

A pressure sensor, located on the O_3 generator and photometer, pressure/flow sensor PCA (see Figure 3-6), 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.

9.7. PHOTOMETER OPERATION

The Model T700 calibrator's optional photometer determines the concentration of Ozone (O_3) in a sample gas drawn through it. Sample and calibration gasses 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.

9.7.1. MEASUREMENT METHOD

9.7.1.1. 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 gasses at Standard Temperature and Pressure (STP) is:

Equation 9-5

$$I = I_0 e^{-\alpha LC} \quad \text{at STP}$$

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 T700, 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 9-6

$$C = \ln \frac{I_o}{I} \times \frac{1}{\alpha L} \quad \text{at STP}$$

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 9-7

$$C = \ln \frac{I_o}{I} \times \frac{1}{\alpha L} \times \frac{T}{273^o K} \times \frac{29.92\,inHg}{P}$$

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 9-8

$$C = \ln \frac{I_o}{I} \times \frac{10^9}{\alpha L} \times \frac{T}{273^o K} \times \frac{29.92\, inHg}{P}$$

The T700 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.

9.7.1.2. 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, physically located on front-left corner of the O_3 generator assembly (see Figure 3-6 and Figure 9-13) 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.

Table 9-2: T700 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 gasses.
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 (**I_0**) during this period.
CYCLE REPEAT EVERY 6 SECONDS	

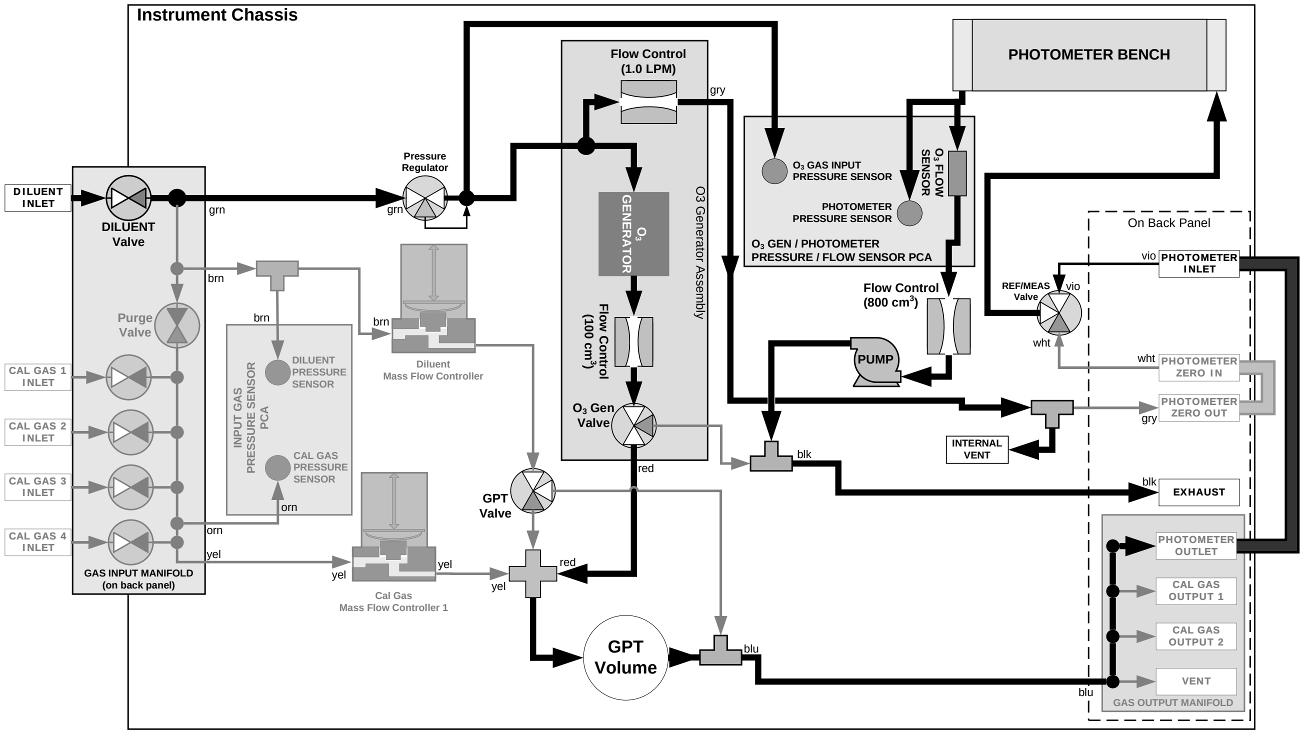


Figure 9-17: O_3 Photometer Gas Flow – Measure Cycle

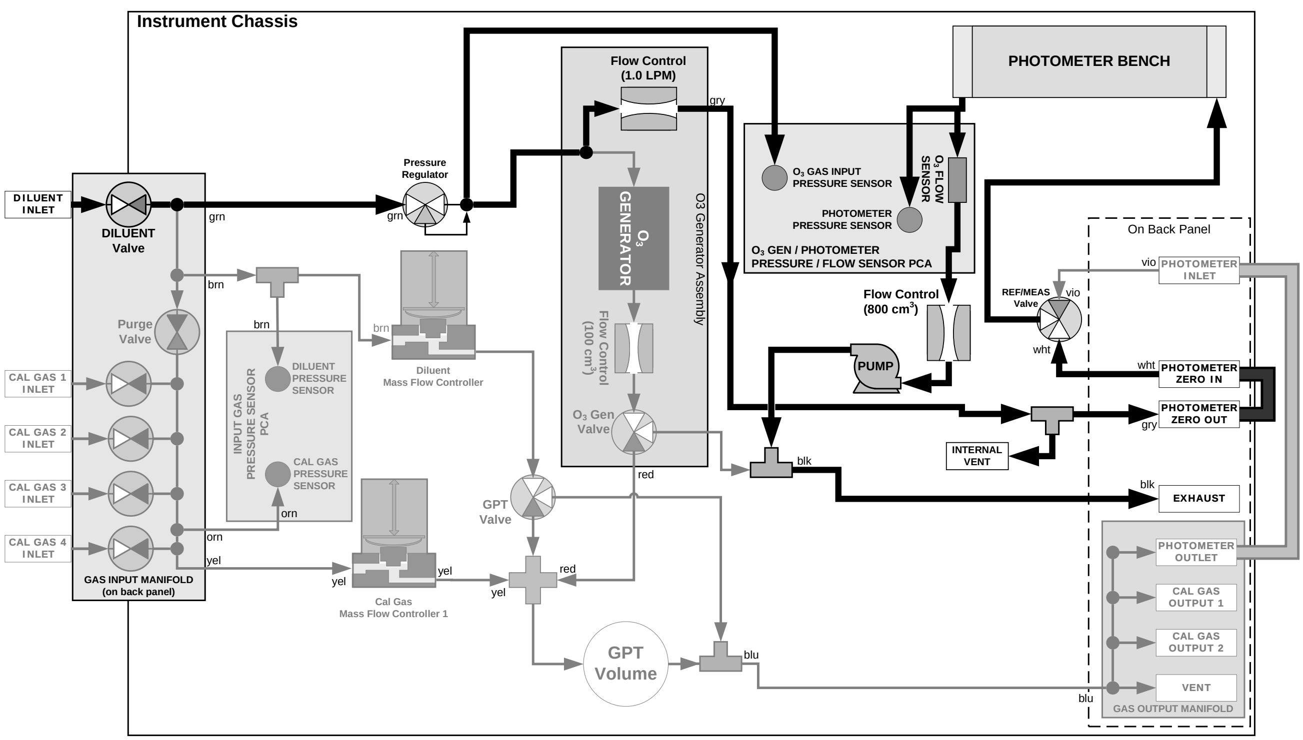


Figure 9-18: O_3 Photometer Gas Flow – Reference Cycle

9.7.1.3. The Absorption Path

In the most basic terms, the T700 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.

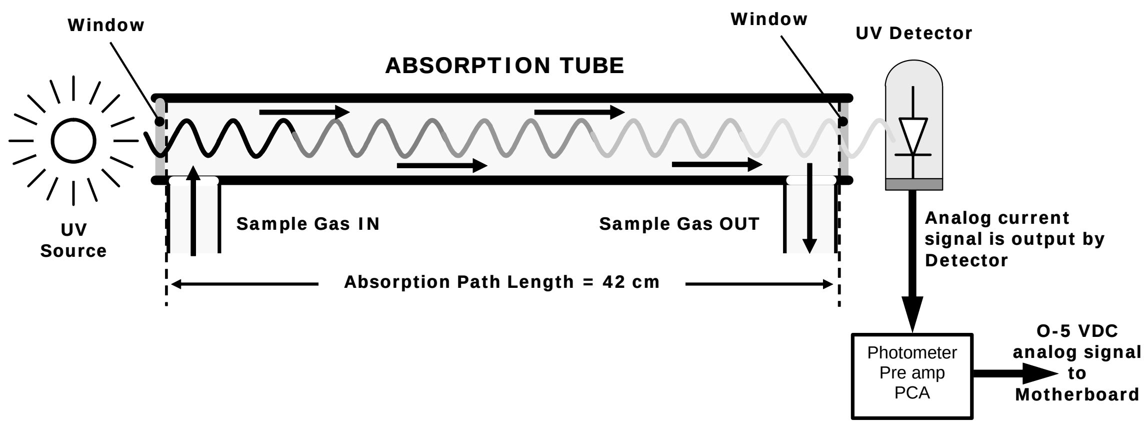


Figure 9-19: O_3 Photometer Absorption Path

9.7.1.4. Interferent Rejection

It should be noted that the UV absorption method for detecting ozone is subject to interference from a number of sources. The T700'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 T700 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.

9.7.2. 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 convert 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.

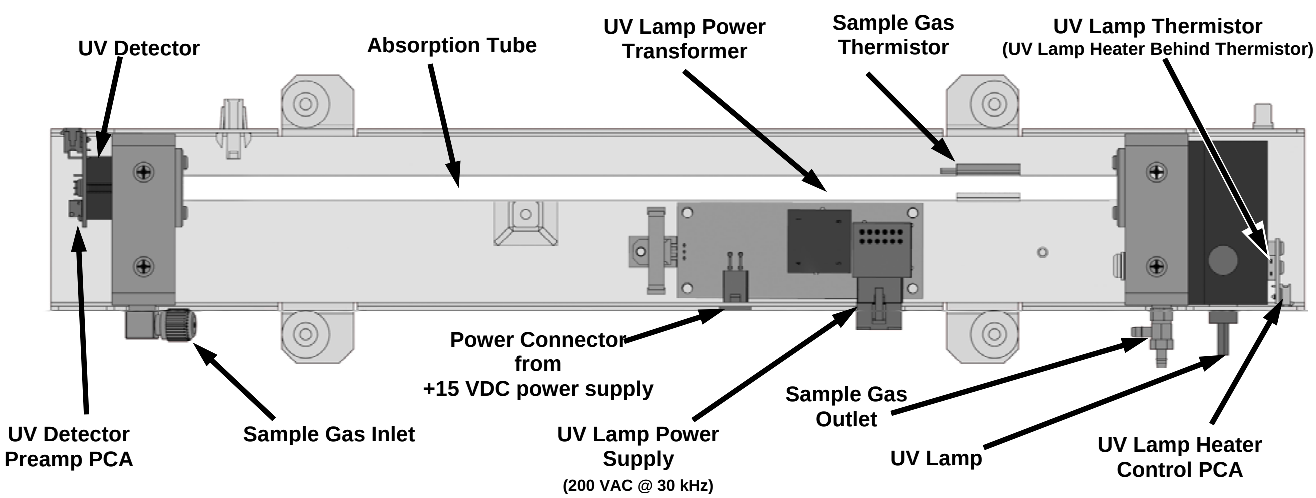


Figure 9-20: O_3 Photometer Layout – Top Cover Removed

9.7.3. PHOTOMETER PNEUMATIC OPERATION

The flow of gas through the photometer is created by a small internal pump that pulls air though the instrument. There are several advantages to this "pull through" configuration. Placing the pump down stream 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 down stream 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 Figure 9-17 and Figure 9-18 for depictions of the airflow related to the photometer.

9.7.4. PHOTOMETER ELECTRONIC OPERATION

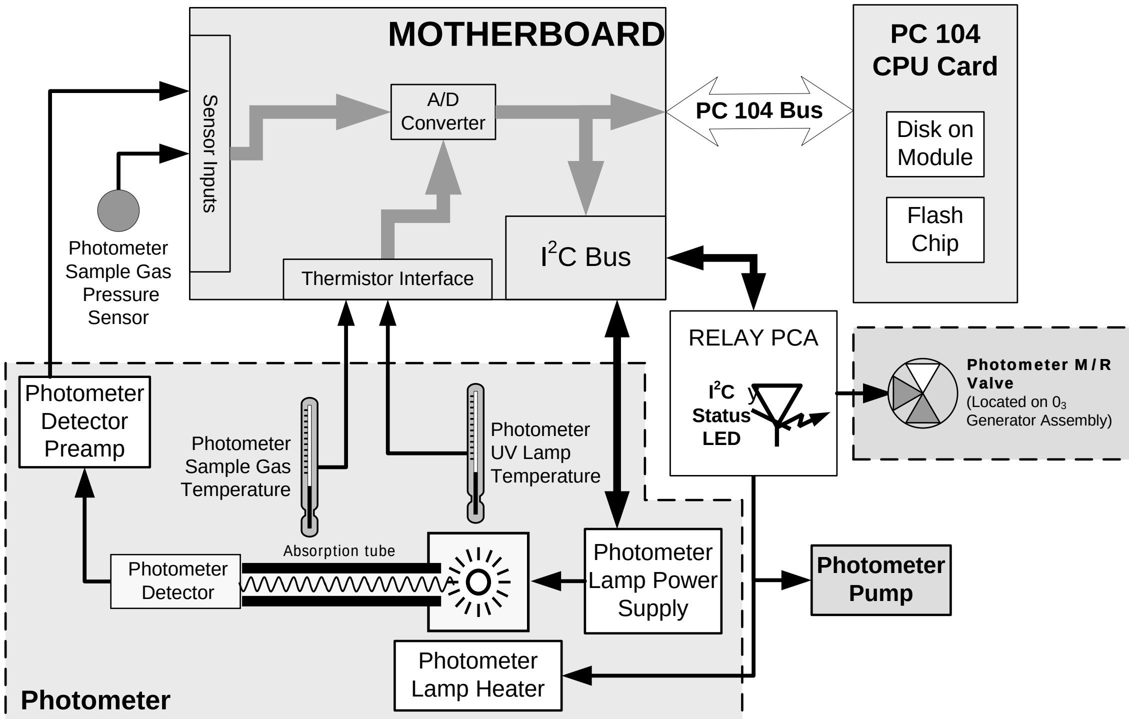


Figure 9-21: O_3 Photometer Electronic Block Diagram

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 which 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 T700's pressure sensors.

9.7.4.1. O_3 Photometer Temperature Control

In order to operate at peak efficiency the UV lamp of the T700's O_3 photometer is maintained at a constant 58ºC. This is intentionally set at a temperature higher than the ambient temperature of the T700'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 9.3.3.2).

The following TEST functions report these temperatures and are viewable from the instrument's front panel:

- **PHOTOLTEMP -** The temperature of the UV Lamp reported in ºC.

- **PHOTOSTEMP** - The temperature of the Sample gas in the absorption tube reported in ºC.

9.7.4.2. 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 9-7). 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 front panel:

- **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.**

10. MAINTENANCE SCHEDULE & PROCEDURES

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 T700 calibrator is maintenance free, there are, however, a minimal number of simple procedures that when performed regularly will ensure that the T700 photometer continues to operate accurately and reliably over its lifetime.

Repairs and troubleshooting are covered in Section 11 of this manual.

10.1. MAINTENANCE SCHEDULE

Table 10-1 shows a typical maintenance schedule for the T700. 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 8.3 for instructions on performing checks.

	**CAUTION** **RISK OF ELECTRICAL SHOCK. DISCONNECT POWER BEFORE PERFORMING ANY OF THE FOLLOWING OPERATIONS THAT REQUIRE ENTRY INTO THE INTERIOR OF THE CALIBRATOR.**

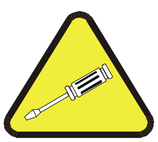
	**CAUTION** **THE OPERATIONS OUTLINED IN THIS SECTION ARE TO BE PERFORMED BY QUALIFIED MAINTENANCE PERSONNEL ONLY.**

Table 10-1: T700 Maintenance Schedule

Item	Action	Freq	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	10.2.2	**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 T700 Calibrator**									
Perform Flow Check	Verify Flow of MFC's	Annually or any time the T700's internal DAC is recalibrated	No	8.1 & 8.2										
Perform Leak Check	Verify Leak Tight	Annually or after any Maintenance or Repair	Yes	10.2.1										
Pneumatic lines	Examine and clean	As needed	Yes if cleaned	- - -										
[1] Only applies to T700 Calibrator's with O_3 photometer options installed.														

10.2. MAINTENANCE PROCEDURES

The following procedures are to be performed periodically as part of the standard maintenance of the T700 calibrator.

10.2.1. AUTO LEAK CHECK

10.2.1.1. Equipment Required

- Four (4) 1/4" Pneumatic caps.
- One (1) 1/8" Pneumatic Cap
- One (1) # 6 hexagonal Driver/Wrench
- One (1) Pneumatic "T" fitting

10.2.1.2. Setup Auto Leak Check

To perform a leak-check on the T700 calibrator:

1. Remove the cover from the calibrator.
2. On Instruments with the optional O_3 photometer installed, the photometer flow sensor PCA and pump must be bypassed:
   - Using a #6 nut driver, remove the hexagonal nut located at the top of the gas outlet of the photometer (see Figure 10-1).
   - Using a #6 nut driver, remove the hexagonal nut located on the fitting on the back side of the Flow/Pressure sensor board (see Figure 10-1).
   - Connect the end of the line removed from the Sensor PCA in Step 3 to the Photometer Outlet Fitting.

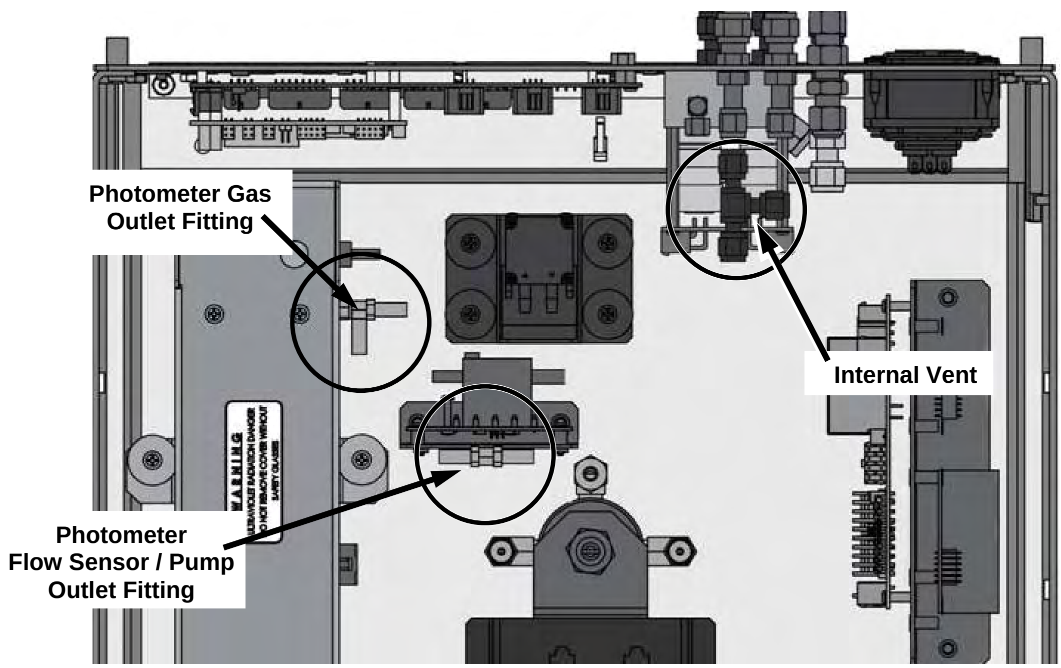


Figure 10-1: Bypassing the Photometer Sensor PCA and Pump

3. Using the 1/8” cap, securely cover the outlet of the internal vent located just behind the valve relay PCA (see Figure 10-1).
4. Use the 1/4" caps to cover the following gas outlet ports on the back of the T700 (see Figure 10-2).
   - Exhaust (Only required for calibrators with O_3 generators install).
   - Both Cal Gas 1 outlet ports.
   - The Vent port.

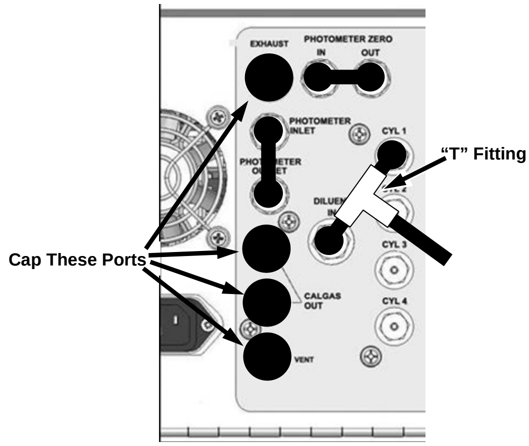


Figure 10-2: Gas Port Setup for Auto-Leak Check Procedure

5. If a bottle of source gas is connected to the CYL 1 port, remove it.

> **NOTE**
>
> **Ensure that the gas outlet of the bottle is CLOSED before disconnecting the gas line from the CYL 1 port.**

6. Connect a gas line from the zero air gas source to the DILUENT IN and to the CYL 1 port using a “T” type pneumatic fitting (see Figure 10-2).

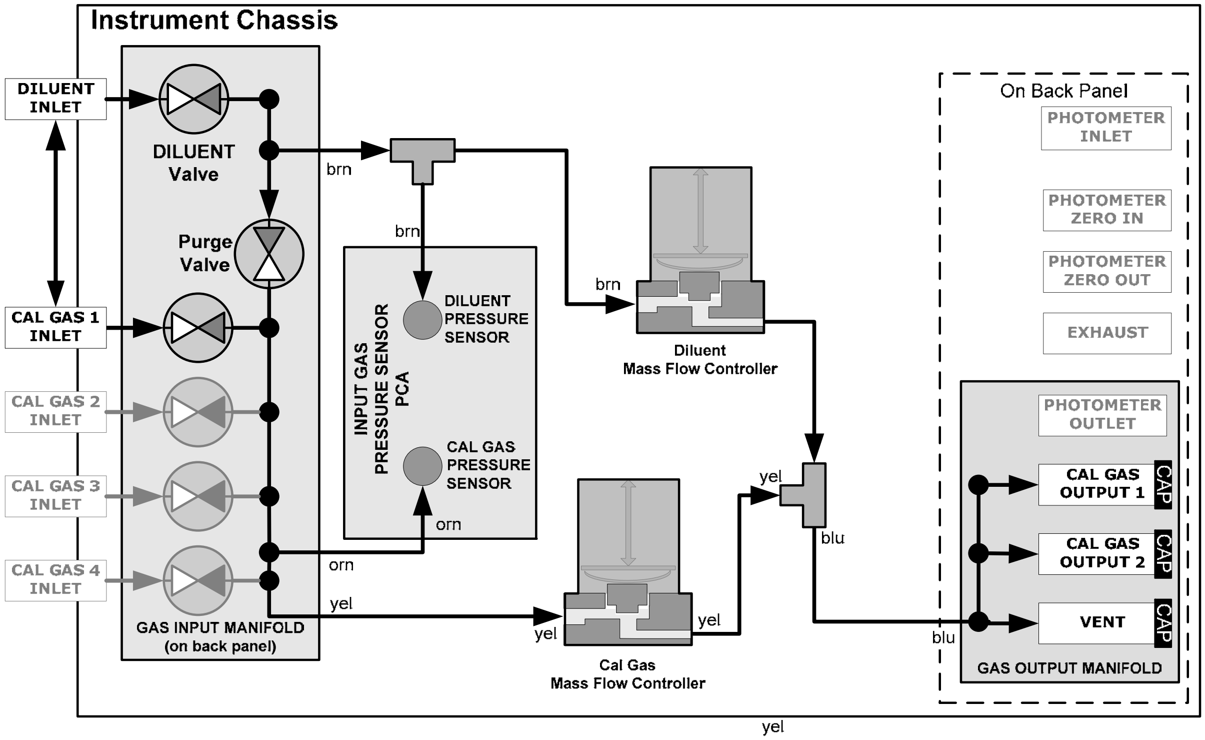


Figure 10-3: Gas Flow for Auto-Leak Check Procedure of Base Model T700's

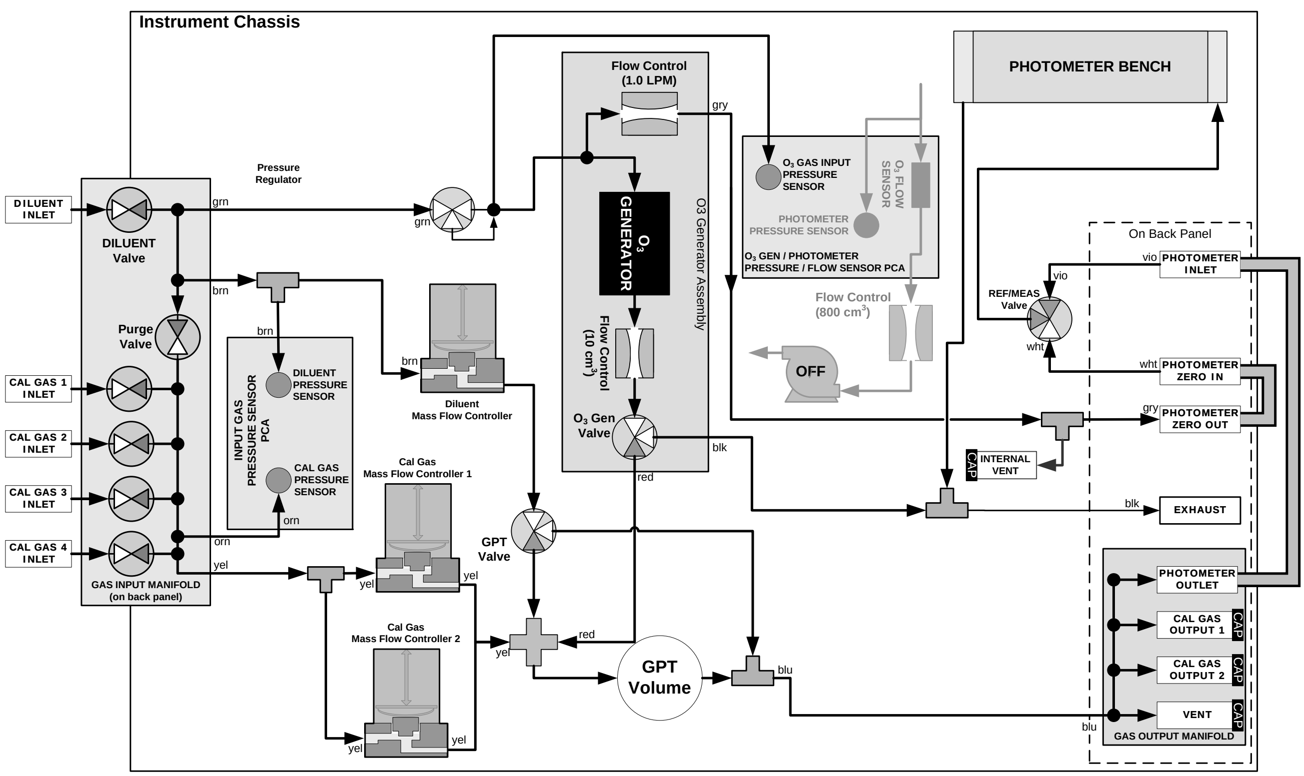
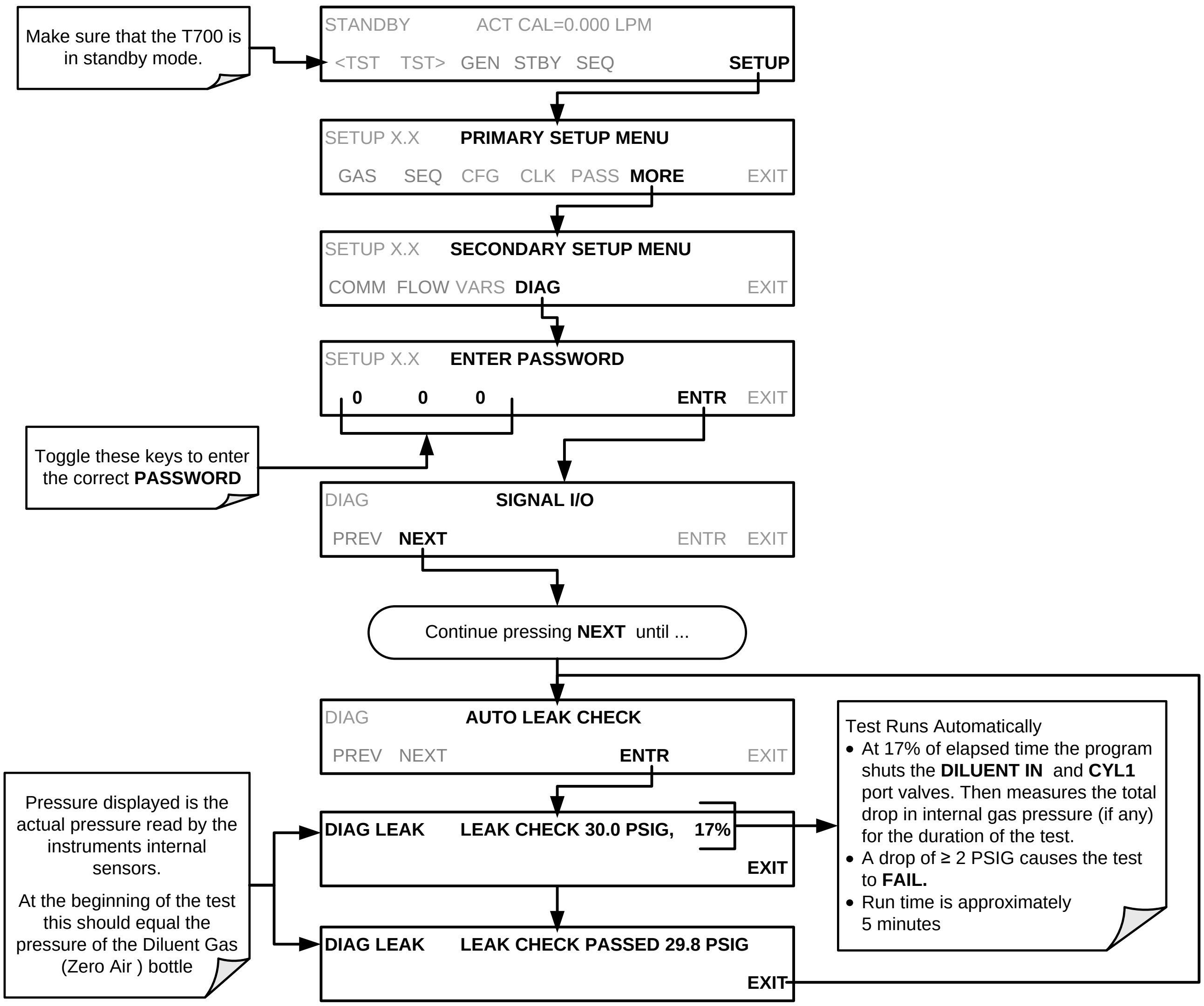


Figure 10-4: Gas Flow for Auto-Leak Check Procedure of T700's with Optional Photometer

10.2.1.3. Performing the Auto Leak Check Procedure

To perform an **AUTO LEAK CHECK**, press:



10.2.1.4. Returning the T700 to Service after Performing an Auto Leak Check

1. Remove all of the caps from the EXHAUST, CAL GAS OUTPUTS (2) and the VENT port and from the internal vent.
2. On instruments with an optional O_3 photometer, reconnect the internal gas lines so that the Sensor PCA and pump are functional.
3. Remove the tee from the DILUENT IN and CYL 1.
4. Reconnect the ZERO AIR SOURCE to the DILUENT IN.
5. Reconnect Cal Gas bottle to CYL 1 and open the bottles outlet port.
6. Replace the calibrator's top cover.
7. The calibrator is now ready to be used.

10.2.2. 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).
    - If there is any noticeable damage to these o-rings, they should be replaced.
10. Re-assemble the tube into the lamp housing and perform an **AUTO LEAK CHECK** on the instrument.

NOTE

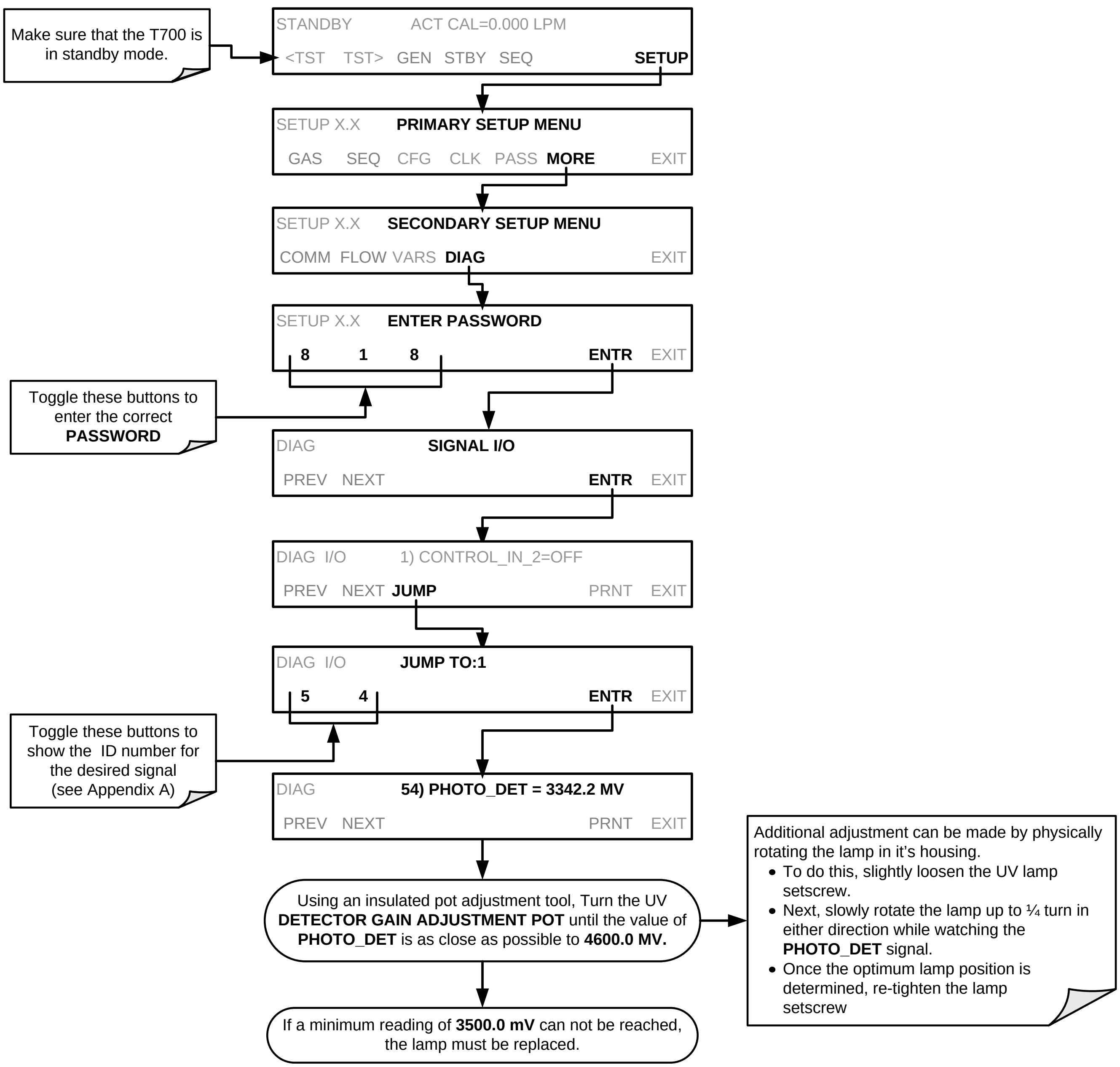
It is important for proper optical alignment that the tube be pushed all the way towards the front of the optical bench when it is reassembled prior to gently retightening the tube retainer screws.

This will ensure that the tube is assembled with the forward end against the stop inside the detector manifold.

10.2.3. UV SOURCE LAMP ADJUSTMENT

This procedure provides in detail the steps for adjustment of the UV source lamp in the optical bench assembly. This procedure should be done 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. Remove the cover from the calibrator.
3. Locate the optional Photometer (see Figure 3-6).
4. Locate the **UV DETECTOR GAIN ADJUST POT** on the photometer assembly (see Figure 10-5).
5. Perform the following procedure:



6. Replace the cover on the calibrator.

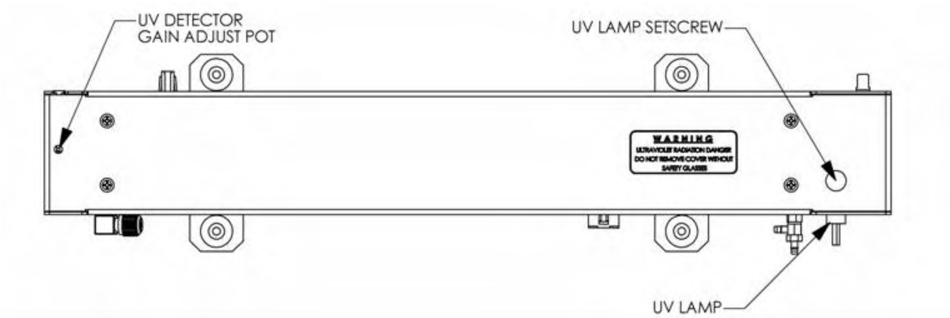


Figure 10-5: Photometer Assembly – Lamp Adjustment / Installation

10.2.4. UV SOURCE LAMP REPLACEMENT

This procedure details the steps for replacement of the UV source lamp in the optical bench assembly. This procedure should be done whenever the lamp can no longer be adjusted as described in Section 10.2.3.

1. Turn the calibrator off.
2. Remove the cover from the calibrator.
3. Locate the Optical Bench Assembly (see Figure 3-6).
4. Locate the UV lamp at the front of the optical bench assembly (see Figure 10-5).
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 10-5) 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 10.2.3, 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 Customer Service for assistance.
    b) Once a lamp position is found that 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. Replace the cover on the calibrator.

NOTE

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.

10.2.5. ADJUSTMENT OR REPLACEMENT OF OZONE GENERATOR UV LAMP

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. Remove the cover from the calibrator.
3. Locate the O_3 generator (see Figure 3-6).

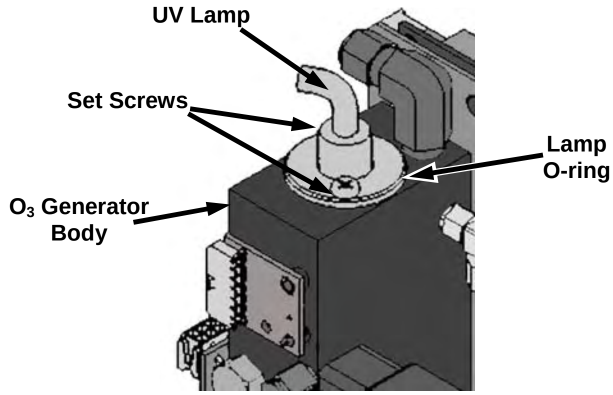


Figure 10-6: O_3 Generator Temperature Thermistor and DC Heater Locations

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.
   - Do not fully tighten the setscrews.
   - The lamp should be able to be rotated in the assembly by grasping the lamp cable.
7. Turn on calibrator and allow it to stabilize for at least 30 minutes.
8. Locate the potentiometer used to adjust the O_3 generator UV output.

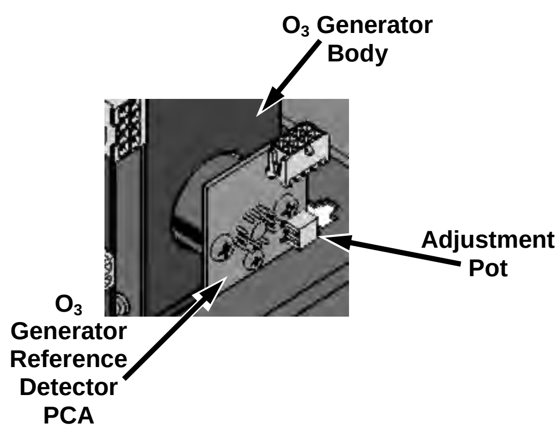
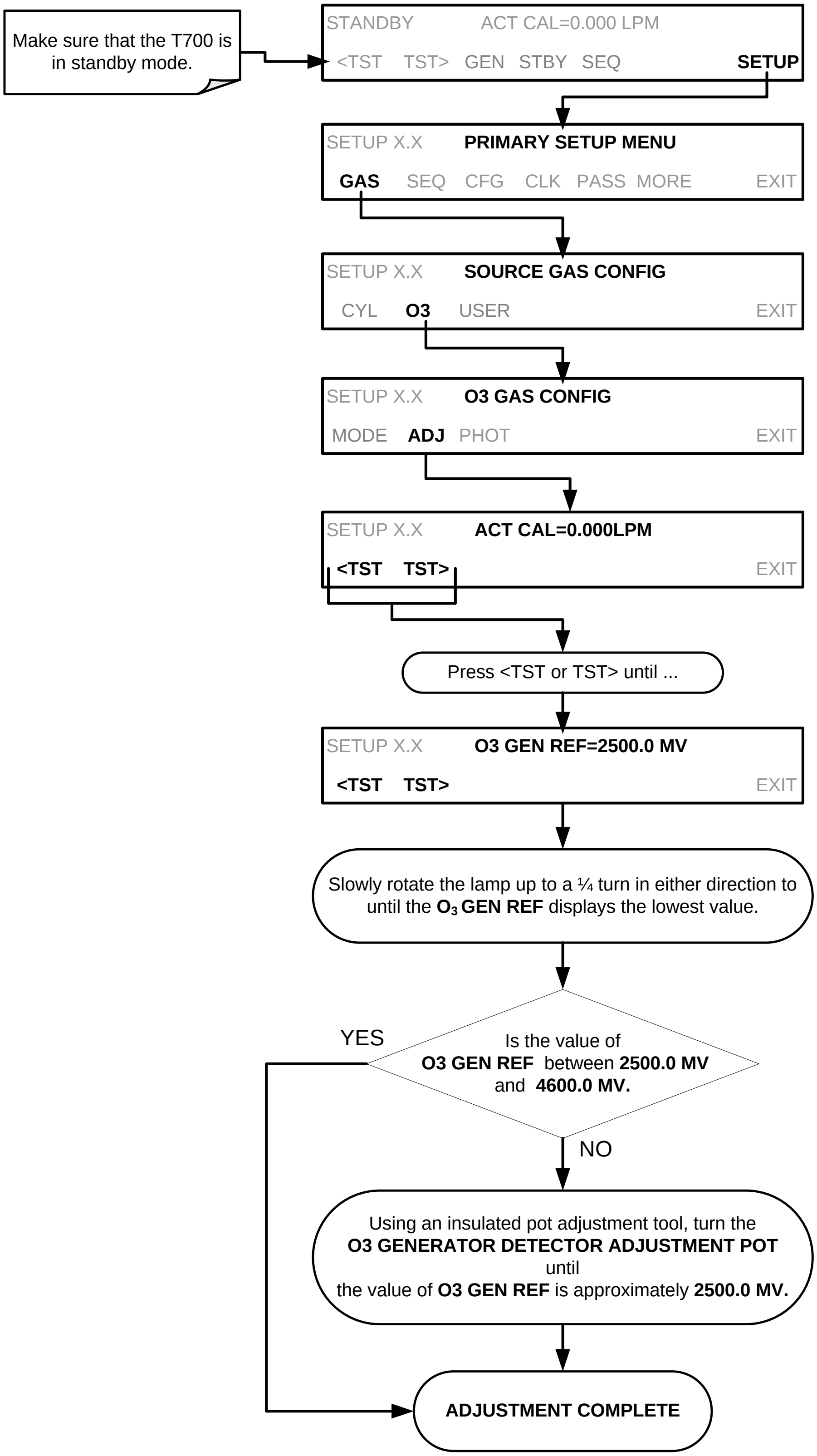


Figure 10-7: Location of O_3 Generator Reference Detector Adjustment Pot

9. Perform the following procedure:

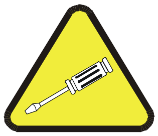


10. Tighten the two setscrews.

11. Replace the calibrator's cover.
12. Perform an auto-leak check (See Section 10.2.1).
13. Perform an Ozone Generator calibration (see Section 8.4).

11. GENERAL TROUBLESHOOTING & REPAIR

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



NOTE
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.**

11.1. GENERAL TROUBLESHOOTING

The T700 Dynamic Dilution 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:

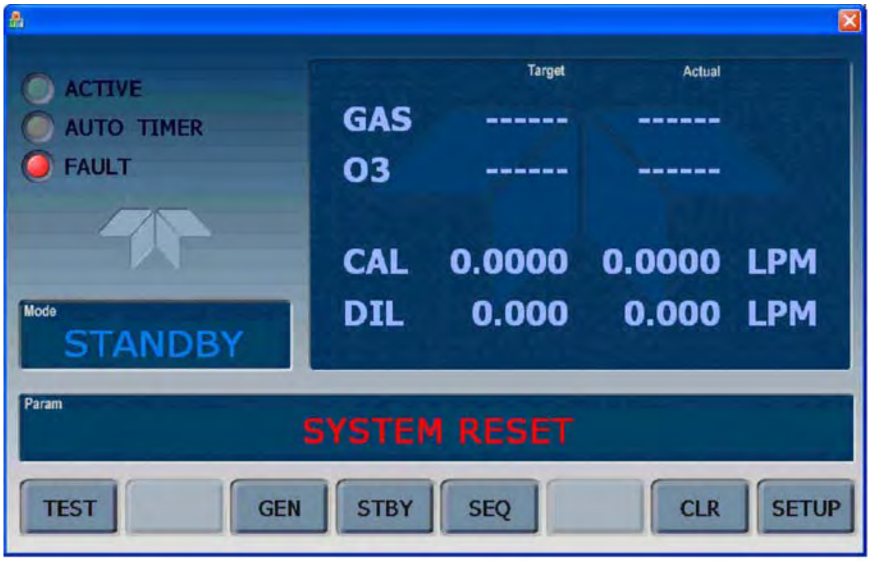
1. Note any warning messages and take corrective action as necessary.
2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.
3. Use the internal electronic status LEDs to determine whether the electronic 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 3.3.4 to confirm that the calibrator's vital functions are working (power supplies, CPU, relay PCA, etc.).
   - See Figure 3-5 and Figure 3-6 for general layout of components and sub-assemblies in the calibrator.
   - See the wiring interconnect diagram and interconnect list in Appendix D.

11.1.1. FAULT DIAGNOSIS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message being displayed on the front panel. Table 11-1 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 (See Section 11.4.3), the relay PCA (See Section 11.4.7), and the motherboard (See Section11.4.11) be confirmed before addressing the specific warning messages.

The T700 will alert the user that a Warning Message is active by flashing the FAULT LED, displaying the 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:



The calibrator will also alert the user via the Serial I/O COMM port(s) and cause the FAULT LED on the front panel to blink.

To view or clear the various warning messages press:

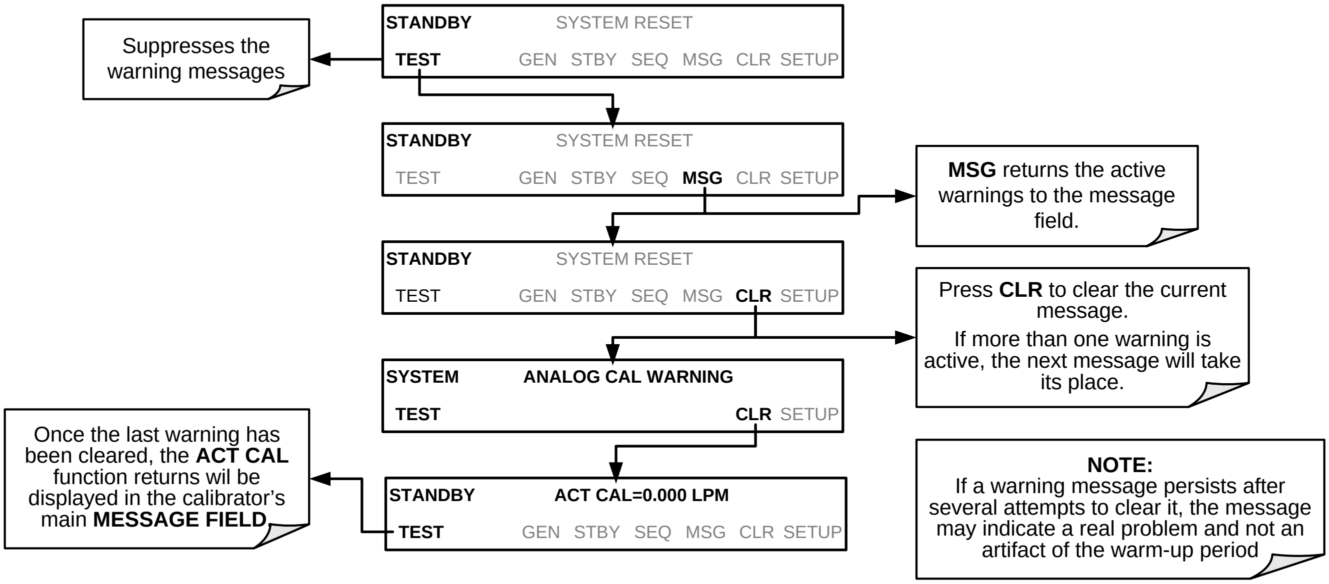


Table 11-1: Front Panel Warning Messages

WARNING	FAULT CONDITION	POSSIBLE CAUSES
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	- Failed Disk-on-Chip - User has erased configuration data
DATA INITIALIZED	Data Storage in DAS was erased.	- Failed Disk-on-Module. - User cleared data.
FRONT PANEL WARN	The CPU is unable to communicate with the front panel display touchscreen	- *WARNING* only appears on Serial I/O COMM Port(s) - Front Panel Display will be frozen, blank or will not respond. - Failed Touchscreen - I^2C Bus failure - Loose Connector/Wiring
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 MFC's 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 T700's internal pneumatics - Failed CAL GAS or DUILUENT 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 GEN REFERENCE WARNING[1]	The O_3 generator's reference detector output has dropped below 50 mV.[1]	Possible failure of: - O_3 generator UV Lamp - O_3 generator reference detector - O_3 generator lamp power supply - 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]	The 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

(table continued)

Table 11-1: Front Panel Warning Messages (cont.)

WARNING	FAULT CONDITION	POSSIBLE CAUSES
PHOTO LAMP STABILITY WARNING	Value output during the Photometer's reference cycle changes from measurements 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) Front Panel Display 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 T700's internal pneumatics - 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
VALVE BOARD WARN	The CPU is unable to communicate with the valve board.	- I^2C Bus failure - Failed valve driver PCA - Loose connectors/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 MFC's 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).

11.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the test functions viewable from the calibrators front panel can be used to isolate and identify many operational problems when combined with a thorough understanding of the calibrators Theory of Operation (see Section 9).

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 11-2 contains some of the more common causes for these values to be out of range.

Table 11-2: Test Functions – Indicated Failures

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
O3 GEN REF[1]	Particularly important in calibrators without the optional O_3 photometer since the reference detector is the primary input for controlling O_3 concentration. Possible causes of faults are the same as **O3 GEN REFERENCE WARNING** from Table 11-1.
O3 FLOW[1]	Gas flow problems directly affect the concentration accuracy of the T700's calibration gas mixtures. - Check for Gas Flow problems.
O3 GEN DRIVE[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 11-1.
O3 LAMP TEMP[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 11-1.
CAL PRESSURE	Affects proper flow rate of Cal gas MFC's. Possible causes of faults are the same as **MFC PRESSURE WARNING** from Table 11-1.
DIL PRESSURE	Affects proper flow rate of Diluent gas MFC's. Possible causes of faults are the same as **MFC PRESSURE WARNING** from Table 11-1.
REG PRESSURE[2]	Same as **REGULATOR PRESSURE WARNING** from Table 11-1.
BOX TEMP	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.
PHOTO MEASURE[2] **&** **PHOTO REFERENCE**[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.
PHOTO FLOW[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.
PHOTO LAMP TEMP[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 11-1.
PHOTO SPRESS[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 11-1.

(table continued)

Table 11-2: Test Functions - Indicated Failures (cont.)

TEST FUNCTION	DIAGNOSTIC RELEVANCE AND CAUSES OF FAULT CONDITIONS.
PHOTO 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
PHOTO 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.
PHOTO OFFSET[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 6.7. ▪ 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

11.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTION

The Signal I/O parameters found under the DIAG Menu combined with a thorough understanding of the instruments Theory of Operation (found in Section 9) 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 11-1 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.

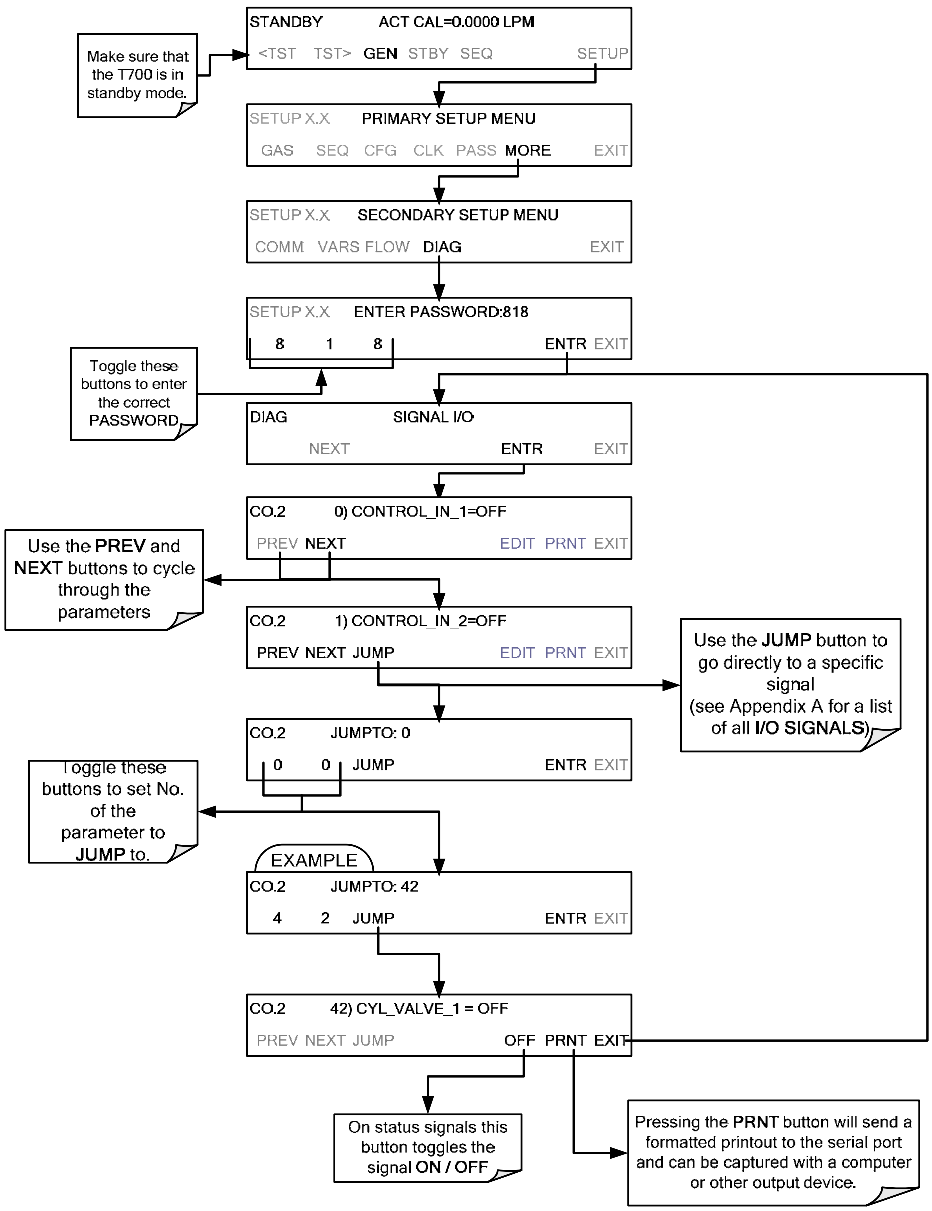


Figure 11-1: Example of Signal I/O Function

11.2. USING THE ANALOG OUTPUT TEST CHANNEL

The signals available for output over the T700's analog output channel can also be used as diagnostic tools. See Section 6.9 for instruction on activating the analog output and selecting a function.

Table 11-3: 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. - < 2000mV – 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	
O3 GEN REF	The raw output of the O_3 generator's reference detector	0 mV	5000 mV	Possible causes of faults are the same as **O3 GEN REFERENCE WARNING** from Table 11-1.
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 11-2.
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 11-1.
CHASSIS TEMP	The temperature inside the T700's chassis (same as **BOX TEMP**)	0 C°	70 C°	Possible causes of faults are the same as **BOX TEMP** from Table 11-2.
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.

11.3. 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.

11.3.1. 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 characters are written to the front panel display but DS5 does not flash then the program files have become corrupted, contact customer service because it may be possible to recover operation of the calibrator. If after 30 – 60 seconds, neither DS5 is flashing nor have any characters been written to the front panel display then the CPU is bad and must be replaced.

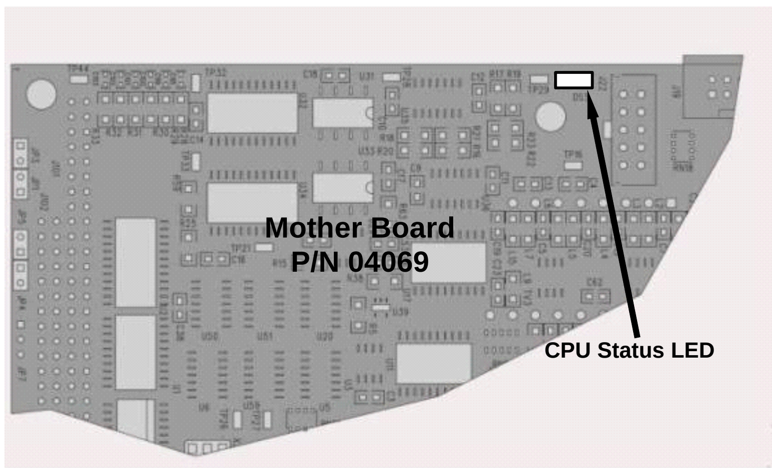


Figure 11-2: CPU Status Indicator

11.3.2. RELAY PCA STATUS LEDS

There are seven LEDs located on the Relay PCA. Some are not used on this model.

11.3.2.1. I^2C Bus Watchdog Status LEDs

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

Table 11-4: 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.

11.3.2.2. O_3 Option Status LEDs

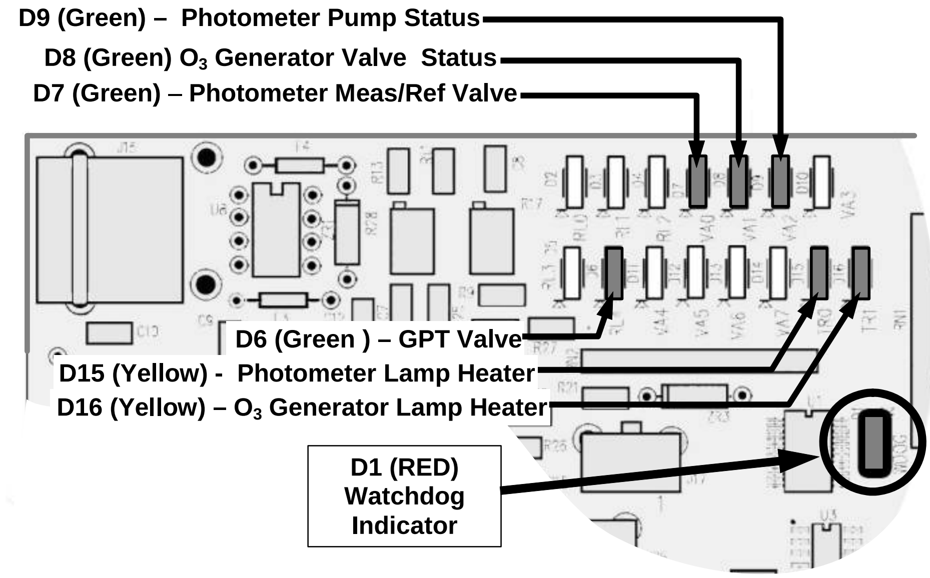


Figure 11-3: Relay PCA Status LEDS Used for Troubleshooting

Table 11-5: Relay PCA Status LED Failure Indications

LED	FUNCTION	SIGNAL I/O PARAMETER		DIAGNOSTIC TECHNIQUE
		ACTIVATED BY	**VIEW RESULT**	
D7[1] Green	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] Green	O_3 Generator Valve Status	**O3_GEN_VALVE**	N/A	
D9[1] Green	Photometer Pump Status	**O3-PUMP-ON**	N/A	
D6[1,2] Yellow	GPT Valve Status	**GPT_VALVE**	N/A	
D15[1] Yellow	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] Green	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.

11.3.3. VALVE DRIVER PCA STATUS LEDS

The Signal I/O submenu also includes VARS that can be used to turn the various input gas valves on and off as part of a diagnostic investigation.

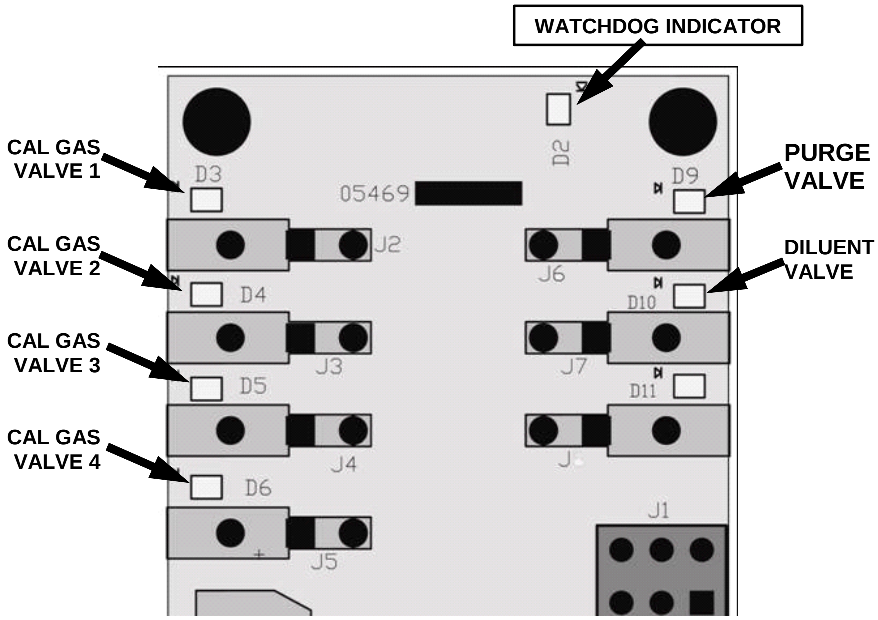


Figure 11-4: Valve Driver PCA Status LEDS Used for Troubleshooting

Table 11-6: Valve Driver Board 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)

Table 11-7: Relay PCA Status LED Failure Indications

LED	FUNCTION	ACTIVATED BY SIGNAL I/O PARAMETER	DIAGNOSTIC TECHNIQUE
D3	**Cal Gas CYL1**	**CYL_VALVE_1**	Valve should audibly change states and LED should glow. If not: • Failed Valve • Failed Valve Driver IC on Relay PCA • Failed Valve Driver Board • Faulty +12 VDC Supply (PS2) • Faulty Connectors/Wiring
D4	**Cal Gas CYL2**	**CYL_VALVE_2**	
D5	**Cal Gas CYL3**	**CYL_VALVE_3**	
D6	**Cal Gas CYL4**	**CYL_VALVE_4**	
D9	**Purge Valve Status**	**PURGE_VALVE**	
D10	**Diluent Valve Status**	**INPUT_VALVE**	

11.4. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the T700 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 if which is actually the cause of the problem being investigated.

11.4.1. VERIFY SUBSYSTEM CALIBRATION

A good first step when troubleshooting the operation of the T700 calibrator is to verify that its major subsystems are properly calibrated. These are:

- The mass flow controllers (see Section 8.2).
- Test Channel D → A conversion (see Section 6.9.2).
- Gas pressure calibration (see Section 8.5).

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

- Photometer calibration (see Section 8.3).
- O_3 generator calibration (see Section 8.4).

11.4.2. AC MAIN POWER

The T700 calibrator's electronic systems will operate with any of the specified power regimes. As long as 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 show a front panel display.

- Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.
- If they do not, check the circuit breaker built into the ON/OFF switch on the instruments front panel.

WARNING

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

11.4.3. 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 11-5 and Table 11-8.

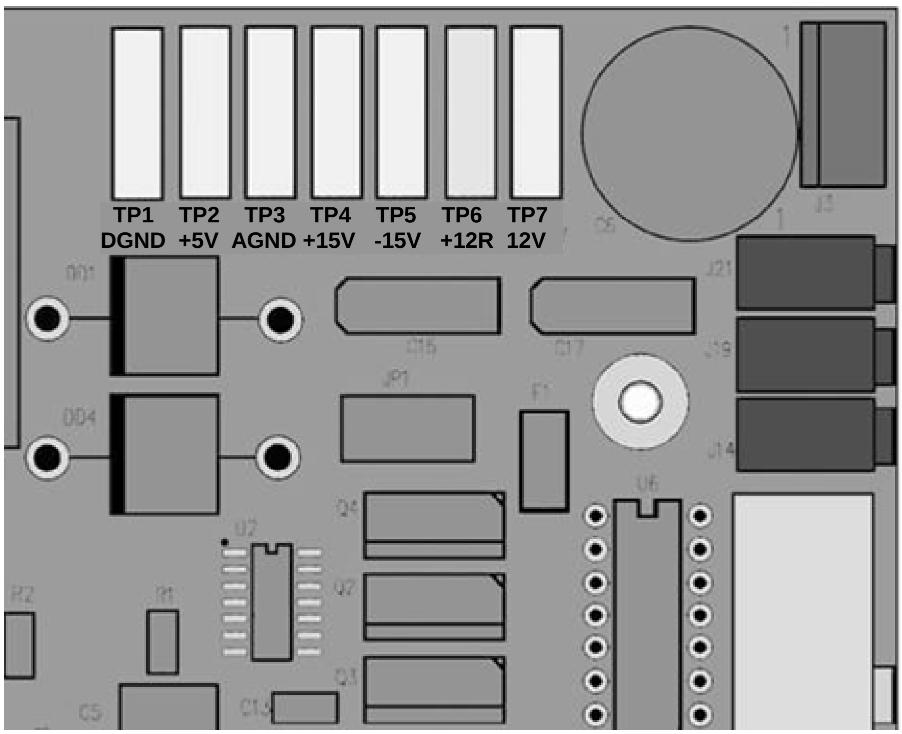


Figure 11-5: Location of DC Power Test Points on Relay PCA

Table 11-8: 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 11-9, 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 11-9: 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

11.4.4. I^{2}C BUS

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

11.4.5. 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.

11.4.6. LCD DISPLAY MODULE

Verify the functioning of the front panel display by observing it when power is applied to the instrument. Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

11.4.7. RELAY PCA

The Relay PCA can be most easily checked by observing the condition of the status LEDs on the Relay PCA (see Section 11.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 11.1.3) 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 11-10 lists the control device associated with a particular function.

Table 11-10: Relay PCA Control Devices

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

11.4.8. VALVE DRIVER PCA

Like the Relay PCA the valve driver PCA is checked by observing the condition of the its status LEDs on the Relay Board (see Section 11.3.2), and using the **SIGNAL I/O** submenu under the **DIAG** menu (see Section 11.1.3) to toggle each LED **ON** or **OFF.**

If D2 on the valve driver board is flashing and the status indicator for the output in question (Gas Cyl 1, Purge Valve, etc.) toggles properly using the Signal I/O function, then the control IC is bad.

11.4.9. INPUT GAS PRESSURE / FLOW SENSOR ASSEMBLY

The input gas pressure/flow sensor PCA, located at the front of the instrument to the left of the MFC's (see Figure 3-6) can be checked with a Voltmeter. The following procedure assumes that the wiring is intact and that the motherboard as well as the power supplies is 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:

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

   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.

11.4.10. 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 3-6) can be checked with a Voltmeter. The following procedure assumes that the wiring is intact and that the motherboard as well as 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 11.4.9).

PHOTOMETER FLOW SENSOR

- Measure the voltage across TP3 and TP1.
  - With proper flow (800 cm^3/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.

11.4.11. MOTHERBOARD

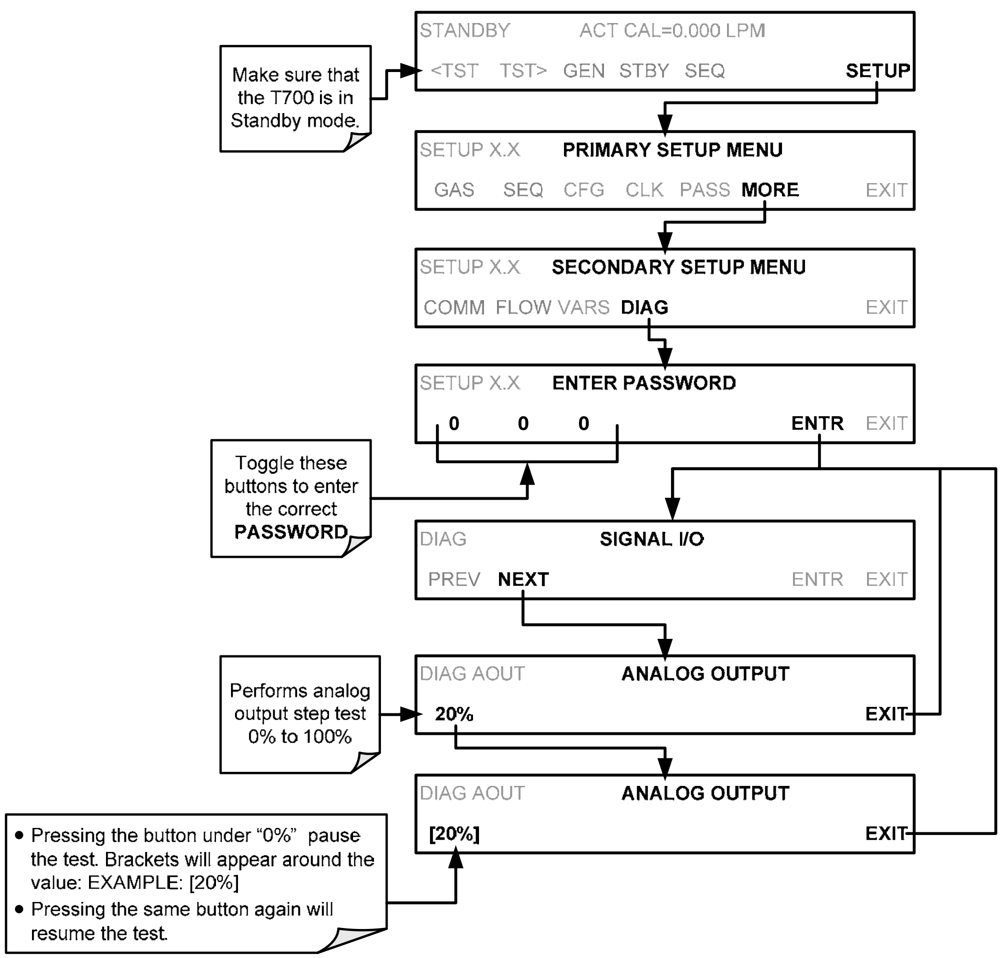
11.4.11.1. A/D Functions

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 to 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 11.1.3 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.

11.4.11.2. 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 as follows:



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 6.9.1.5).

Table 11-11: Analog Output Test Function – Nominal Values Voltage Outputs

		FULL SCALE OUTPUT OF VOLTAGE RANGE (see Section 6.9.1.3)			
		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.

11.4.11.3. 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 Section11.1.3), 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 11-12: 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

11.4.11.4. Control Inputs

Table 11-13: T700 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 11.1.3), 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**".

11.4.11.5. 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 11-14).
4. Under the **DIAG→ SIGNAL I/O** menu (See Section 11.1.3), 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 11-14: 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**

11.4.12. 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 front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

11.4.13. 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 being connected to an active network jack.
- Check the internal cable connection between the Ethernet card and the CPU board.

11.4.14. RS-232 COMMUNICATIONS

11.4.14.1. 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 7.1.2 for connector and pin-out information.
- The BAUD rate and protocol are incorrectly configured. See Section 7.1.3.
- If a modem is being used, additional configuration and wiring rules must be observed. See Section 7.2.
- Incorrect setting of the DTE-DCE Switch is set correctly. See Section 7.1.1.
- Verify that the cable (P/N 03596) that connects the serial COMM ports of the CPU to J12 of the motherboard is properly seated.

11.4.14.2. 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 7.1.1.
3. Check to ensure the set up command is correct. See Section 7.2.1.
4. Verify that the Ready to Send (RTS) signal is at logic high. The T700 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 7.1.3.
6. Use the RS-232 test function to send "w" characters to the modem, terminal or computer. See Section 7.1.5.
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.

11.4.15. 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 T700 will perform poorly.

11.4.15.1. 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 11.1.3). This parameter will vary with ambient temperature, but at ~30^{o}C (6-7° above room temperature) the signal should be ~1450 mV.

11.4.15.2. 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.

11.4.15.3. 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 58^{o}C set point is ~8.1k ohms.

11.4.15.4. 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.

11.5. TROUBLE SHOOTING THE OPTIONAL O_3 PHOTOMETER

11.5.1. 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.

11.5.1.1. Noisy or Unstable O_3 Readings at Zero

- Check for leaks in the pneumatic system as described in Section 10.2.1.
- Confirm that the Zero gas is free of Ozone.
- Confirm that the Source Lamp is fully inserted and that the lamp hold-down thumb-screw is tight.
- Check for a dirty Absorption Cell and/or pneumatic lines. Clean as necessary as described in Section 10.2.2.
- 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.

11.5.1.2. Noisy, Unstable, or Non-Linear Span O_3 Readings

- Check for leaks in the pneumatic systems as described in Section 10.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section 11.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 10.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 11.4.11.1.
- Confirm the Sample Temperature, Sample Pressure and Sample Flow readings are correct. Check and adjust as required.

11.5.1.3. Slow Response to Changes in Concentration

- Check for dirty absorption cell and clean or replace as necessary as described in Section 10.2.2.
- Check for pneumatic leaks as described in Section 10.2.1.
- 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 3.3.10).

11.5.1.4. The Analog Output Signal Level Does Not Agree With Front Panel Readings

- Confirm that the recorder offset (see Section 6.9.1.5) is set to zero.
- Perform an AIO calibration (see Section 6.9.2) and photometer dark calibration (see Section 8.3.5).

11.5.1.5. Cannot Zero

- Check for leaks in the pneumatic system as described in Section 10.2.1.
- 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 3.3.10).

11.5.1.6. Cannot Span

- Check for leaks in the pneumatic systems as described in Section 10.2.1.
- Check for proper operation of the meas/ref switching valve as described in Section11.5.2.
- Check for dirty absorption cell and clean or replace as necessary as described in Section 10.2.2.
- Check for operation of the A/D circuitry on the motherboard. See Section 11.4.11.1.
- 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 3.3.10).

11.5.2. CHECKING MEASURE / REFERENCE VALVE

To check the function of the photometer's measure / reference valve:

1. Set the calibrator's front panel display to show the **PHOTO REFERENC**E test function (see Section 6.1).
2. Follow the instruction in Sections 8.3.3 and 8.3.4.1 for performing a zero point calibration of the photometer.
   - Press X**ZRO** and allow the calibrator to stabilize.
3. Before completing the calibration by pressing the **ZERO** button, note of the displayed value.
4. Press the final Zero button then press "**NO**" when asked, "**ARE YOU SURE**".
5. Follow the instruction in Sections 8.3.4.2 for performing a span point calibration of the photometer.
   - Press **XSPN** and allow the calibrator to stabilize.
6. Before completing the calibration by pressing the **SPAN** button, note of the displayed value of **PHOTO REFERENCE**.
   - If the O_3 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.
7. Press the final Zero button then press "**NO**" when asked, "**ARE YOU SURE**".

11.5.3. 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 11.4.3.

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 9-20):

- +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 I^2C 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.

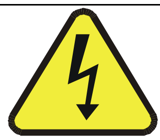
11.6. TROUBLE SHOOTING THE OPTIONAL O_3 GENERATOR

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.

11.6.1. CHECKING THE UV SOURCE 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. 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 11.4.3.
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 9-20):
   - +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 I^2C 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.

11.7. REPAIR PROCEDURES

11.7.1. 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, fold down the rear panel by loosening the mounting screws.
3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.
5. Remove the nylon 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 rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

11.8. TECHNICAL ASSISTANCE

If this manual and its troubleshooting & repair sections do not solve your problems, technical assistance may be obtained from "

TELEDYNE API, CUSTOMER SERVICE,
9480 CARROLL PARK DRIVE
SAN DIEGO, CALIFORNIA 92121-5201
USA

Toll-free Phone:	**800-324-5190**
Phone:	**858-657-9800**
Fax:	**858-657-9816**
Email:	**api-sales@teledyne.com**
Website:	**http://www.teledyne-api.com/**

Before you contact customer service, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.teledyne-api.com/forms/.

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12. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne API considers the prevention of damage caused by the discharge of static electricity to be extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

12.1. HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.

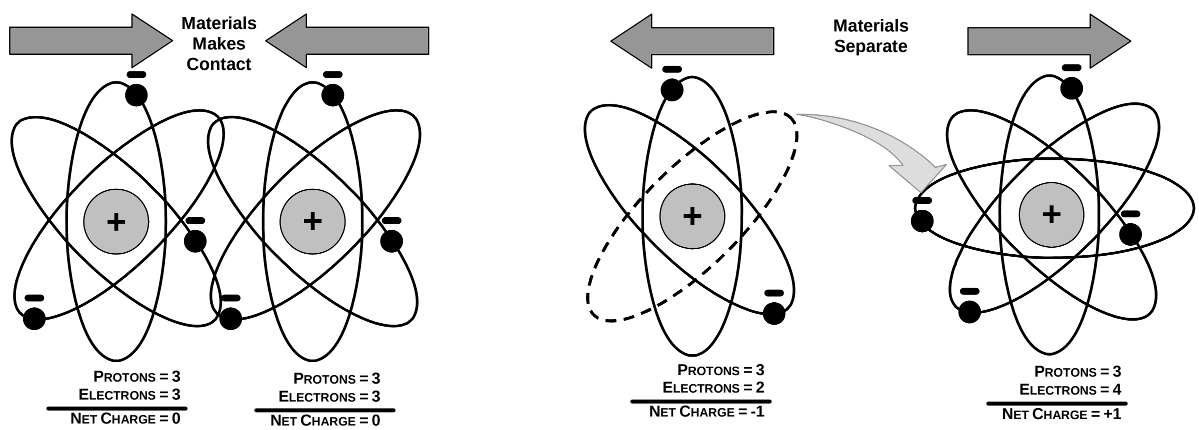

Figure 12-1: Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step, electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam™ pellets during shipment can also build hefty static charges

Table 12-1: Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

12.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 12-1 with the those shown in the Table 12-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 12-2: Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
This Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.
- When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.
- A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.
- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

12.3. COMMON MYTHS ABOUT ESD DAMAGE

I didn't feel a shock so there was no electro-static discharge: The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.

I didn't touch it so there was no electro-static discharge: Electro Static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.

It still works so there was no damage: Sometimes the damaged caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

Static Charges can't build up on a conductive surface: There are two errors in this statement.

Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

As long as my analyzer is properly installed, it is safe from damage caused by static discharges: It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

12.4. BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

12.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation.

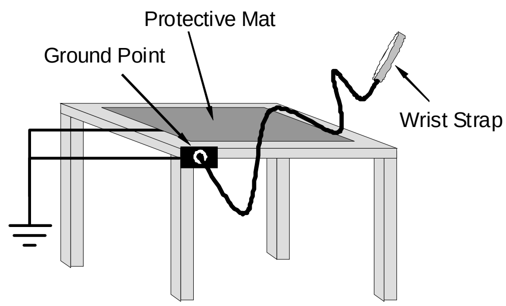

Figure 12-2: Basic Anti-ESD Work Station

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer. An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

Simply touching a grounded piece of metal is insufficient. While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.

Always store sensitive components and assemblies in anti-ESD storage bags or bins: Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags. The famous, pink-poly bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

While this layer may equalizes any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive, grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

Never use ordinary plastic adhesive tape near an ESD sensitive device or to close an anti-ESD bag. The act of pulling a piece of standard plastic adhesive tape, such as Scotch® tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

12.4.2. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

12.4.2.1. Working at the Instrument Rack

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply

1. Attach your anti-ESD wrist strap to ground before doing anything else.
    - Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis.
    - This will safely connect you to the same ground level to which the instrument and all of its components are connected.
2. Pause for a second or two to allow any static charges to bleed away.
3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.
4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.
5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

12.4.2.2. Working at an Anti-ESD Work Bench

When working on an instrument of an electronic assembly while it is resting on a anti-ESD work bench

1. Plug you anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.
2. Pause for a second or two to allow any static charges to bleed away.
3. Only open any anti-ESD storage bins or bags containing sensitive devices or assemblies after you have plugged your wrist strap into the workstation.
    - Lay the bag or bin on the workbench surface.
    - Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.
4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.
    - Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.
5. Place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin before unplugging your wrist strap.
6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

12.4.2.3. Transferring Components from Rack to Bench and Back

When transferring a sensitive device from an installed Teledyne API analyzer to an anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.
2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
3. Before using the bag or container allow any surface charges on it to dissipate:
    - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
    - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
    - In either case wait several seconds.
4. Place the item in the container.
5. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
    - Folding the open end over isolates the component(s) inside from the effects of static fields.
    - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.
6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:
    - Connect your wrist strap to ground.
    - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
    - If you are at a anti-ESD work bench, lay the container down on the conductive work surface.
    - In either case wait several seconds.
7. Open the container.

12.4.2.4. Opening Shipments from Teledyne API's Customer Service

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne API ships all electronic components and assemblies in properly sealed anti-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped ensure that you:

Always unpack shipments from Teledyne API's Customer Service by:

1. Opening the outer shipping box away from the anti-ESD work area.
2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.
3. Follow steps 6 and 7 of Section 12.4.2.3 above when opening the anti-ESD container at the work station.
4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

12.4.2.5. Packing Components for Return to Teledyne API's Customer Service

Always pack electronic components and assemblies to be sent to Teledyne API's Customer Service in anti-ESD bins, tubes or bags.

WARNING

- **DO NOT use pink-poly bags.**
- **NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly**
  - **This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape**
- **DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape**

1. Never carry the component or assembly without placing it in an anti-ESD bag or bin.
2. Before using the bag or container allow any surface charges on it to dissipate:
   - If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.
   - If you are at an anti-ESD workbench, lay the container down on the conductive work surface.
   - In either case wait several seconds.
3. Place the item in the container.
4. Seal the container. If using a bag, fold the end over and fastening it with anti-ESD tape.
   - Folding the open end over isolates the component(s) inside from the effects of static fields.
   - Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

NOTE

If you do not already have an adequate supply of anti-ESD bags or containers available, Teledyne API's Customer Service department will supply them (see Section 11.8 for contact information).

Follow the instructions listed above for working at the instrument rack and workstation.

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