California Environmental Protection Agency

COMMUNITY AIR MONITORING BRANCH

STANDARD OPERATING PROCEDURE

FOR

CONTINUOUS DETERMINATION OF HYDROGEN SULFIDE IN AMBIENT AIR USING A TELEDYNE T101 MONITOR

CAMB SOP 360

First Edition

Monitoring and Laboratory Division

November 2018

DISCLAIMER: Mention of any trade name or commercial product in this Standard Operating Procedure does not constitute endorsement or recommendation of this product by the Air Resources Board. Specific brand names and instrument descriptions listed in the Standard Operating Procedure are for equipment used by the Air Resources Board laboratory.

California Environmental Protection Agency

CALIFORNIA AIR RESOURCES BOARD

Approval of Standard Operating Procedure

Title: Continuous Determination of Hydrogen Sulfide in Ambient Air Using a Teledyne T101 Monitor

SOP: CAMB SOP 360, First Edition

Section: Advanced Monitoring Techniques Section

Branch: Community Air Monitoring Branch

Division: Monitoring and Laboratory Division

Approval: This SOP has been reviewed and approved by

Walter Ham, Manager
Advanced Monitoring Techniques Section
Community Air Monitoring Branch

11/29/18
Date

Kenneth Stroud, Chief
Community Air Monitoring Branch

11-29-18
Date

Table of Contents

Glossary

cm^3/min	Cubic centimeter per minute
DAS	Data Acquisition system
kg	Kilogram
Hz	Hertz
In-Hg-A	Inch of Mercury Absolute Pressure
IZS	Internal zero span
lbs	Pounds
LED	Light Emitting Diode
mg/m^3	milligram per cubic meter
$\mu g/m^3$	microgram per cubic meter
nm	nanometer
NIST	National Institute of Standards and Technology
PMT	Photo multiplier tube
ppb	part per billion
ppm	part per million
PRES	Pressure
RMS	Root Mean Square
SRM	Standard Reference Material
V	Volt
UV	Ultraviolet

Instrument Setup Features and Functions

ACAL	Auto Calibration Feature
AUTO	Auto Range Mode
CFG	Analyzer Configuration
CLK	Internal Clock Configuration
CLR	Clear
DIAG	System Diagnostic Features
COMM	External Communication Channel Configuration
ENTR	Enter
IND	Independent Range Mode
MSG	Message
PASS	Calibration Password Security
RNGE	Analog Output Reporting Range Configuration
SNGL	Single Range Mode
VARS	System Diagnostic Features

1.0 Scope

This SOP describes a method to use the UV fluorescence H_2S monitor (Teledyne Model T101). This SOP covers principles of operation, measurement interference, the operation of measurements, calibration, quality assurance, routine maintenance and troubleshooting.

2.0 Principles of Operation

2.1 This equipment determines the concentration of hydrogen sulfide (H_2S) by converting H_2S to sulfur dioxide (SO_2) which is then determined through a fluorescence approach. Equipment specifications are is provided in Table 2.1

2.2 During the sampling, ambient air is drawn (in series) through: a sample particulate filter to remove ambient particles, a hydrocarbon scrubber to remove hydrocarbons, and finally a SO_2 scrubber to remove the ambient SO_2 prior to introducing into the chemical converter. The sampling flowrate is 700 ml/min. A schematic of the sampling flow is shown in Figure 2.1.

2.3 H_2S in the ambient air is converted to SO_2 through high-temperature catalytic oxidation. The converter is most efficient at 315°C.

2.4 SO_2 produced from H_2S is exposed to 214nm UV light to create an excited state molecule (SO_2*). The SO_2* molecule quickly returns to its ground state by releasing a photon (at 330 nm) to return to the lower energy ground state giving off the excess energy in the form of a photon.

2.5 The amount of emitted light at 330 nm is directly related to the SO_2 concentration, which is used to quantify H_2S concentration.

2.6 The quantification of SO_2 as a proxy for H_2S allows this equipment to measure SO_2 by bypassing the sampling flow from the SO_2 scrubber and the catalytic converter.

Table 2.1 Basic unit specifications

PARAMETER	DESCRIPTION
Ranges	H_2S: Min 0-50 ppb Full scale; Max 0-10 ppm Full scale SO_2: Up to 0-20 ppm Full scale (selectable, independent ranges and auto ranging supported)
Measurement Units	ppb, ppm, µg/m3, mg/m3 (selectable)
Zero Noise[1]	<0.2 ppb (RMS)
Span Noise[1]	<0.5% of reading (RMS) above 50 ppb
Lower Detectable Limit[2]	0.4 ppb
Zero Drift (24 hours)	<0.5 ppb
Span Drift (24 hours)	<0.5% of full scale
Lag Time	20 seconds

PARAMETER	DESCRIPTION
Rise/Fall Time[1]	<120 seconds to 95%
Linearity	1% of full scale
Precision	0.5% of reading above 50 ppb
Sample Flow Rate	650 cm^3/min ±10%
Temperature Coefficient	< 0.1% per ^oC
Voltage Coefficient	< 0.05% per V
Temperature Range	5-40^oC
Humidity Range	0 - 95% RH, non-condensing
Dimensions H x W x D	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)
Weight, Analyzer (Basic Configuration)	41 lbs (18.3 kg) 45 lbs (20.5 kg) w/internal pump
AC Power	100V-120V, 60 Hz (202W); 220V-240V, 50 Hz (200W)
Analog Output Ranges	10 V, 5V, 1V, 0.1V (selectable)
Analog Output Resolution	1 part in 4096 of selected full-scale voltage
Recorder Offset	±10%
Environmental	Installation category (over-voltage category) II; Pollution degree 2
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital status outputs 6 opto-isolated digital control inputs 4 analog outputs
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs
For indoor use at altitudes ≤ 2000m only	

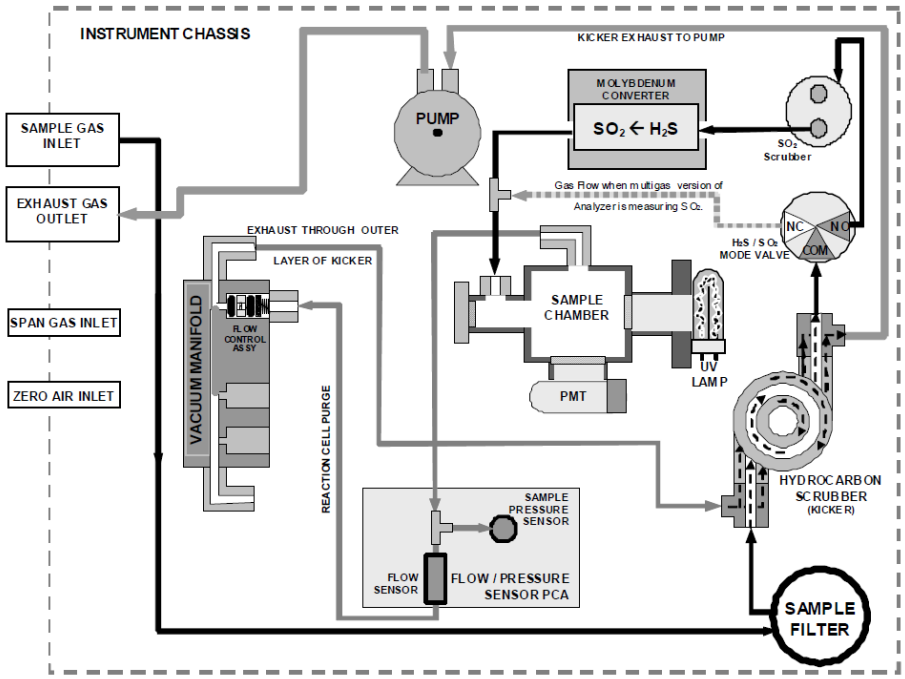

Figure 2.1 Schematic of the sampling flow path.

3.0 Measurement Interferences

The fluorescence method for detecting H_2S is subject to interference from a number of sources. This equipment has been designed to reject interference from most of these sources.

3.1 The measurement of H_2S as SO_2 causes atmospheric SO_2 and hydrocarbons to interfere the measurements of H_2S high. The fluorescence emitted from the decay of SO_2* originated from H_2S cannot be distinguished from light produced from the decay of the excited state of ambient SO_2 and hydrocarbons. Some hydrocarbons, such as xylene and naphthalene, fluoresce in a similar fashion to SO_2. By employing the respective scrubber for SO_2 and hydrocarbons, the measurement interference from SO_2 and hydrocarbons can be eliminated.

3.2 High levels of nitric oxide (NO) interfere with H_2S measurements as NO fluoresces in a spectral range similar to SO_2. An optional optical filter can be used to improve the rejection of the interference from NO; however, this optical filter is not included with this equipment.

3.3 Ozone interferes with H_2S measurements through the absorbance of UV light given off by the decaying SO_2* prior to quantification. By shortening the light path between

SO_2* fluorescence and the detector, the effect of ozone on measurements is negated for this equipment operation.

3.4 The SO_2* molecule can return to its ground state by reacting with other molecule (including nitric oxide, carbon dioxide, water vapor and oxygen), rather than the intended fluorescence pathway. These reactions are referred as a third body quenching effect. This quenching effect is negligible for ambient measurements. However, specific steps must be taken when this equipment is used for stack application where concentrations of some or all of these molecules are very high.

3.5 Stray light can be a significant interfering factor for the spectroscopic (light based) technique used by this equipment. Several approaches have been used to negate these effects, including: usage of a light tight sample chamber, completely opaque tubing connected to the sample chamber, optical filters, and measurements of the background light.

4.0 Qualification Personnel

A technical background is not required for instrument operation. New operators need to undergo hands-on training prior to operation by a trained user provided the current operator. New operators must be familiar with safety information described in Section **5.0 Safety.**

5.0 Safety

5.0 To avoid personal injury we recommend that two persons lift and carry the analyzer for moving. Disconnect all cables and tubing from analyzer before moving it.The $H_2S \rightarrow SO_2$ converter operates at 315 °C. Severe burns can result if the assembly is not allowed to cool. Do not handle the assembly until it is at room temperature - This may take several hours.

5.2 Some operations of this instrument need to be carried out with the analyzer open and running. Exercise caution to avoid electrical shocks. Do not shorten or touch electric connections with metallic tools while operating inside the analyzer. Use common sense when operating inside a running analyzer.

5.3 Power connection must have functioning ground connection. Do not defeat the ground wire on power plug.

6.0 Field Operation

6.1 Instrument Installation

6.1.1 This instrument must be installed in a temperature-controlled enclosure (between 5 °C and 40 °C). Temperature must remain above the dew point (non-condensing), and the relative humidity less than 90 percent.

6.1.2 This instrument can be mounted on a rack or any flat surface.

6.1.3 The sampling inlet setup should follow US EPA guidance for SO_2 (Title 40, Code of Federal Regulations Part 58 Appendix E). The probe or at least 80 percent of the monitoring path must be located between 2 and 15 meters above ground. The instrument must be at least 1 meter vertically and horizontally away from any supporting structures.

6.2 Instrument Startup

6.2.1 Connect all sampling and exhaust lines to the sampling and exhaust ports, respectively if not connected. The sampling and exhaust ports are located at the rear panel of this equipment. Figure 6.1 shows a schematic of the rear panel. Sample inlet pressure of any gas should not exceed 0.5 in-Hg above ambient, and ideally should be equal to the atmospheric pressure.

6.2.2 Connect the data logger to the analog output connecter if a data logger is used.

6.2.3 Connect power cord if not connected.

6.2.4 Check the ventilation clearance around the equipment. The minimum clearance is 4 inches for the back, 1 inch for the sides and 1 inch above and below the equipment.

6.2.5 Turn on the instrument once all connections are complete. The Power On/Off switch is located on the front panel (Figure 6.2).

6.2.6 The pump and exhaust fan should start immediately once the instrument is turned on.

6.2.7 The front panel display will briefly show a logo splash screen at the start of initialization.

6.2.8 The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring H_2S gas. The mode box shows “SAMPLE” and the green light is on (Figure 6.3)

6.2.9 A 60-minute warm-up period is needed prior to collecting sample data.

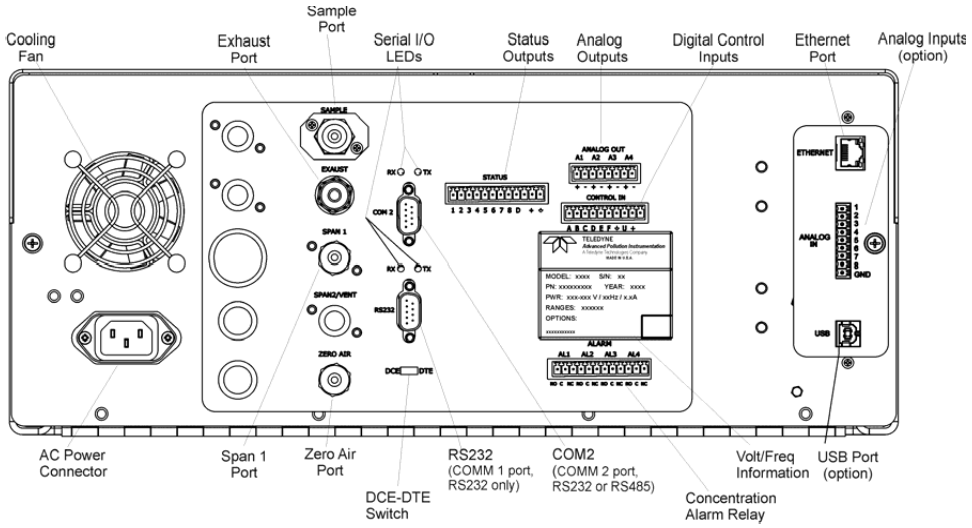

Figure 6.1 Rear panel of the instrument.

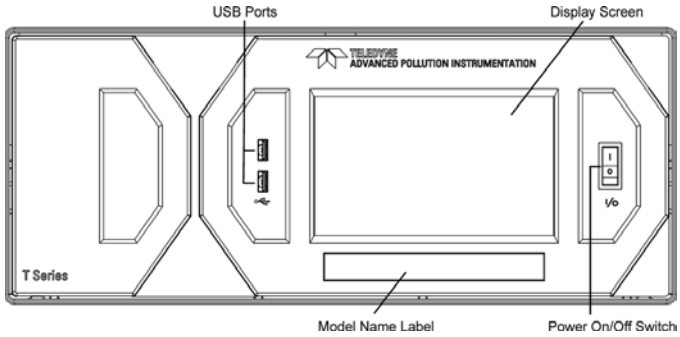

Figure 6.2 Front panel of the instrument.

6.3 Display Screen and Touch Control

Figure 6.3 shows the touch control display screen. This section describes the information accessible using the display screen.

6.3.1 The LEDs on the display screen indicate the Sample, Calibration and Fault states;

6.2.1.1 Green sample light

a. OFF indicates that the unit is not operating in sample mode. The Data acquisation system is disabled;
b. ON indicates that sample mode is active and data is being collected;

c. BLINKING indiscates the unit is operating in sample mode, but the DAS hold-off mode is on. No data is stored.

6.2.1.2 Yellow CAL light

a. OFF indicates auto CAL is disabled;
b. ON indicates that auto CAL is enabled;
c. BLINKING indicates that the unit is in calibration mode.

6.2.1.3 Red Fault light

a. OFF indicates that no warnings exist;
b. BLINKING indicates that warning exist;

6.3.2 The gas concentration field (Conc) displays real-time readouts for the primary gas and for the secondary gas if installed.

6.3.3 The mode field shows what mode the analyzer is currently in, as well as messages and data (Param).

6.3.4 Along the bottom of the screen is a row of touch control buttons; only those that are currently applicable will have a label. Table 3-1 provides detailed information for each component of the screen.

Figure 6.3 Map of the display the screee.

6.4 Operating Modes

This analyzer has two primary operating modes: SAMPLE and SETUP In this section we discuss the uses and operation of each mode.

6.4.1 SAMPLE Mode

A series of test functions is available at the front panel while the analyzer is in SAMPLE mode. The test functions can be viewed by pressing the '<TST' and 'TST>' buttons repeatedly in either direction. The definitions of these test functions are provided in Table 6.1.

Table 6.1 Test Function Defined.

DISPLAY	PARAMETER	UNITS	DESCRIPTION
RANGE	Range - - Range1 Range2	PPB, PPM, µGM & mGM	The full scale limit at which the reporting range of the analyzer's ANALOG OUTPUTS are currently set. THIS IS NOT the physical range of the instrument. If IND or AUTO Range modes have been selected, two RANGE functions will appear, one for each range.
H_2S STB	Stability	PPB	Standard deviation of H2S Concentration readings. Data points are recorded every ten seconds. The calculation uses the last 25 data points.
SAMP FL	Sample Flow	cm^3/min (cc/m)	The flow rate of the sample gas through the sample chamber.
PRES	Sample Pressure	in-Hg-A	The current pressure of the sample gas as it exits the sample chamber, measured after the sample chamber.
PMT	PMT Signal	mV	The raw output voltage of the PMT.
NORM PMT	NORMALIZED PMT Signal	mV	The output voltage of the PMT after normalization for temperature/pressure compensation (if activated).
UV LAMP	Source UV Lamp Intensity	mV	The output voltage of the UV reference detector.
LAMP RATIO	UV Source lamp ratio	%	The current output of the UV reference detector divided by the reading stored in the CPU's memory from the last time a UV Lamp calibration was
STR. LGT	Stray Light	ppb	The offset due to stray light recorded by the CPU during the last zero- point calibration performed.
DRK PMT	Dark PMT	mV	The PMT output reading recorded the last time the UV source lamp shutter was closed.
DRK LMP	Dark UV Source Lamp	mV	The UV reference detector output reading recorded the last time the UV source lamp shutter was closed.
SO2 SLOPE	SO_2 measurement Slope	-	The sensitivity of the instrument as calculated during the last calibration activity. The slope parameter is used to set the span calibration point of the analyzer.
SO2 OFFS	SO_2 measurement Offset	mV	The overall offset of the instrument as calculated during the last calibration activity. The offset parameter is used to set the zero point of the analyzer response.
H2S SLOPE	H_2S measurement Slope	-	The sensitivity of the instrument as calculated during the last calibration activity. The slope parameter is used to set the span calibration point of the analyzer.

DISPLAY	PARAMETER	UNITS	DESCRIPTION
H2S OFFS	H_2S measurement Offset	mV	The overall offset of the instrument as calculated during the last calibration activity. The offset parameter is used to set the zero point of the analyzer response.
HVPS	- -	V	The PMT high voltage power supply.
RCELL TEMP	Sample Chamber Temp	°C	The current temperature of the sample chamber.
BOX TEMP	Box Temperature	°C	The ambient temperature of the inside of the analyzer case.
PMT TEMP	PMT Temperature	°C	The current temperature of the PMT.
IZS TEMP	IZS Temperature	°C	The current temperature of the internal zero/span option. Only appears when IZS option is enabled
CONV	$H_2S \rightarrow SO_2$	°C	The current temperature of the catalytic converter that changes the

6.4.2 Instrument Startup Messages

Warning messages might appear during the warm-up period because internal temperatures and other conditions may be outside of specified limits. If warning messages persist after 60 minutes, investigate their cause using the troubleshooting guidelines in **Section 9.0**.

The message can be viewed and cleared by pressing the button sequence in Figure 6.4. A brief description of the various warning messages is included in Table 6.1

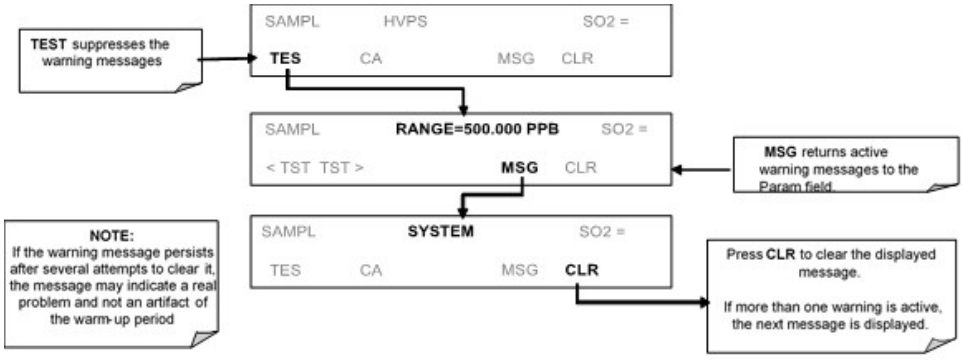

Figure 6.4 Button sequence to view and clear messages.

Table 6.2 Possible messages at the startup

WARNING MESSAGE	MEANING
ANALOG CAL WARNING	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
BOX TEMP WARNING	The temperature inside the T101 chassis is outside the specified limits.
CANNOT DYN SPAN	Remote span calibration failed while the dynamic span feature was set to active
CANNOT DYN ZERO	Remote zero calibration failed while the dynamic zero feature was set to active
CONFIG INITIALIZED	Configuration was reset to factory defaults or was erased.
SHUTTER WARNING	Dark offset above limit specified indicating that too much stray light is present in the sample chamber.
DATA INITIALIZED	DAS data storage was erased.
HVPS WARNING	High voltage power supply for the PMT is outside of specified
IZS TEMP WARNING	On units with IZS options installed: The permeation tube temperature is outside of specified limits.
PMT DET WARNING	PMT detector output outside of operational limits.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL TEMP WARNING	Sample chamber temperature is outside of specified limits.
REAR BOARD NOT DET	The CPU is unable to communicate with the motherboard.
RELAY BOARD WARN	The firmware is unable to communicate with the relay board.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SAMPLE PRESS WARN	Sample pressure outside of operational parameters.
SYSTEM RESET	The computer was rebooted.
UV LAMP WARNING	The UV lamp intensity measured by the reference detector reading too low or too high

6.5 SETUP Mode

6.5.1 Available Analog Output Signals

6.5.1.1 The analyzer has three active analog output signals, accessible through a connector on the rear panel (Figure 6.5).

6.5.1.2 All three outputs can be configured either at the factory or by the user for full scale outputs of 0.1 VDC, 1 VDC, 5 VDC or 10 VDC.

6.5.1.3 In the basic configuration, the A1 and A2 channels output a signal proportional to the H_2S concentration of the sample gas.

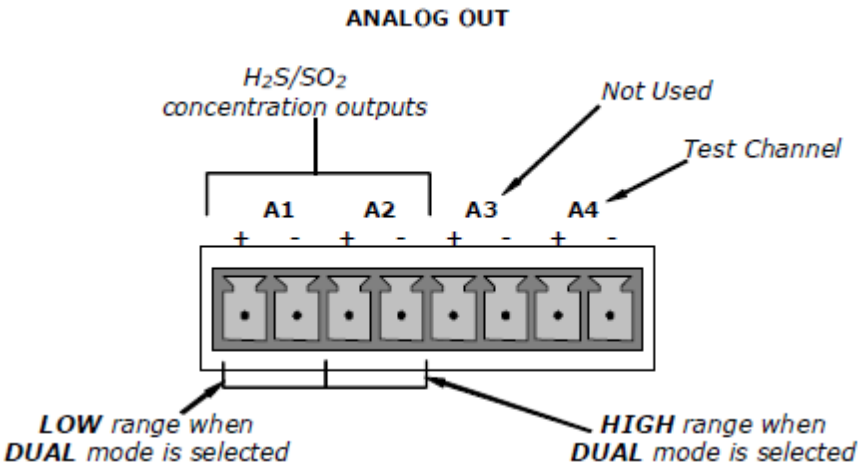

Figure 6.5 Analog out connector.

6.5.2 Reporting Range Modes

The T101 provides three analog output range modes to choose from: single range, independent range, and auto. The actual analog signal output depends on whether or not the analyzer includes a SO_2/H_2S multigas measurement option, and if so which measurement mode is selected.

6.5.2.1 Single range (SNGL) mode: This mode sets a single maximum range for the analog output. If single range is selected (see Section 6.4.3), both outputs are slaved together and will represent the same measurement span (e.g. 0-50 ppm); however, their electronic signal levels may be configured differently. In SO_2/H_2S multigas measurement mode, the two inputs are measuring different gases although the two measurements scales are identical.

6.5.2.2 Independent range (IND) mode: This mode allows the A1 and A2 outputs to be configured with different measurement spans (see Section 6.4.4), separate electronic signal levels (see Section 6.6), and, if the instrument is equipped with the SO_2/H_2S multigas measurement option, different gas measurements.

6.5.2.3 Auto range (AUTO) mode: As in single range mode, both outputs are slaved together and will represent the same measurement span; however this mode gives the analyzer the ability switch to automatically switch between the two user selected ranges (High and Low). This switching occurs dynamically as the concentration value fluctuates (see Section 6.4.5).

6.5.3 Single Range Mode

Single range mode is the default range mode for the analyzer, , and all analog concentration outputs are set to the same reporting range. This reporting range can be set to any value between 5.0 and 20000 ppb.

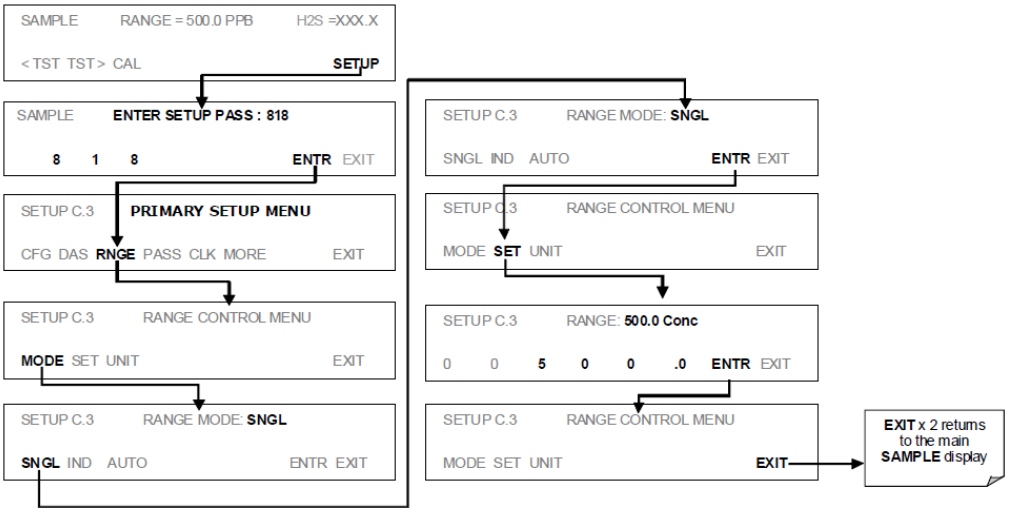

Figure 6.6 Button sequence to set the reporting range mode to the SNGL.

6.5.4 Independent Range Mode

Selecting independent range mode allows the A1 and A2 outputs to be configured with different measurement ranges. The analyzer software calls these two ranges LOW and HIGH. The LOW range setting corresponds with the analog output labeled A1 on the rear panel of the instrument. The HIGH range setting corresponds with the A2 output. While the software names these two ranges LOW and HIGH, they do not have to be configured that way.

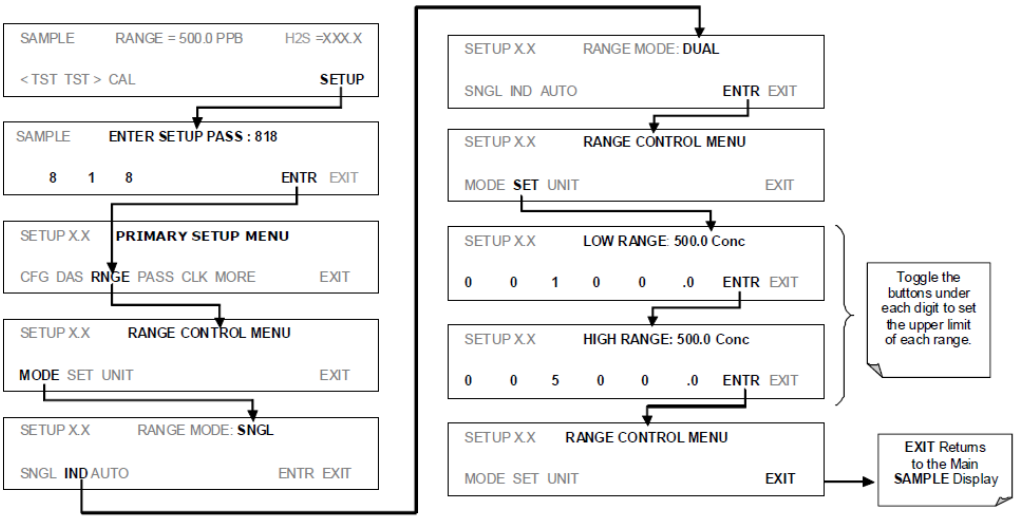

Figure 6.7 Button sequence to set the reporting range mode to IND.

6.5.5 Auto Range Mode (AUTO)

In AUTO range mode, the analyzer automatically switches the reporting range between two user-defined ranges (low and high). The unit will switch from low range to high range when the H_2S concentration exceeds 98% of the low range span. The unit will return from high range back to low range once both the H_2S concentration falls below 75% of the low range span.

In AUTO Range mode the instrument reports the same data in the same range on both the A1 and A2 outputs when set up to measure a single gas (H_2S or SO_2), and automatically switches both outputs between ranges as described above.

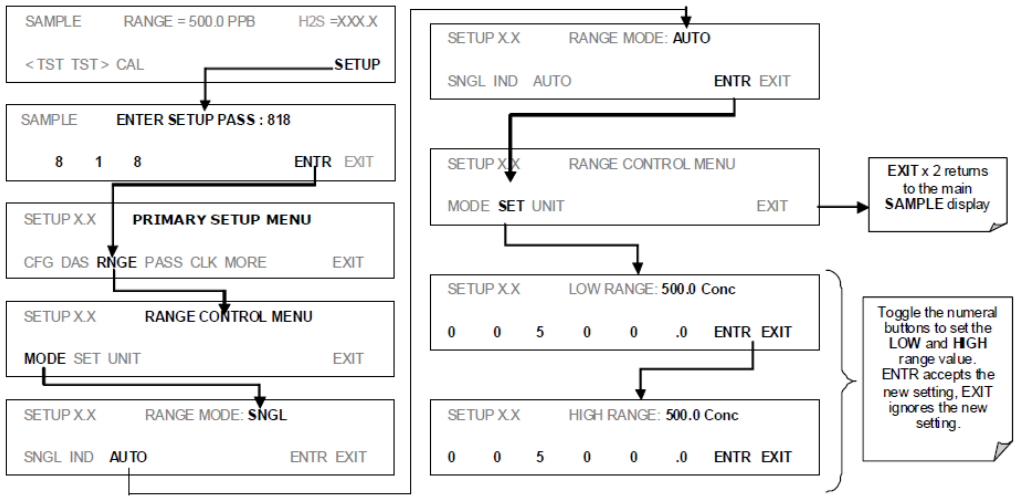

Figure 6.8 Button sequence to set the reporting range to AUTO.

6.6 Range Unit

The analyzer can display concentrations in different units. Figure 6.9 shows how to change the displayed unit.

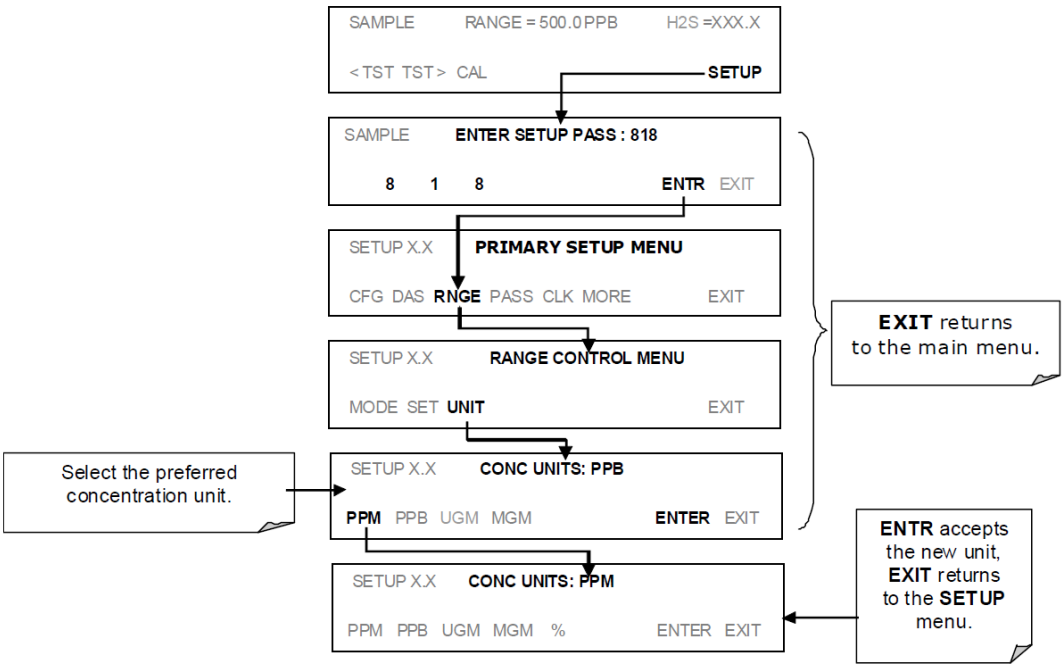

Figure 6.9 Button sequence to change the displayed unit.

6.7 Analog output signal type and range span selection

To select an output signal type and level for one output channel, activate the Analog I/O Configuration Menu first; then, follow Figure 6.10.

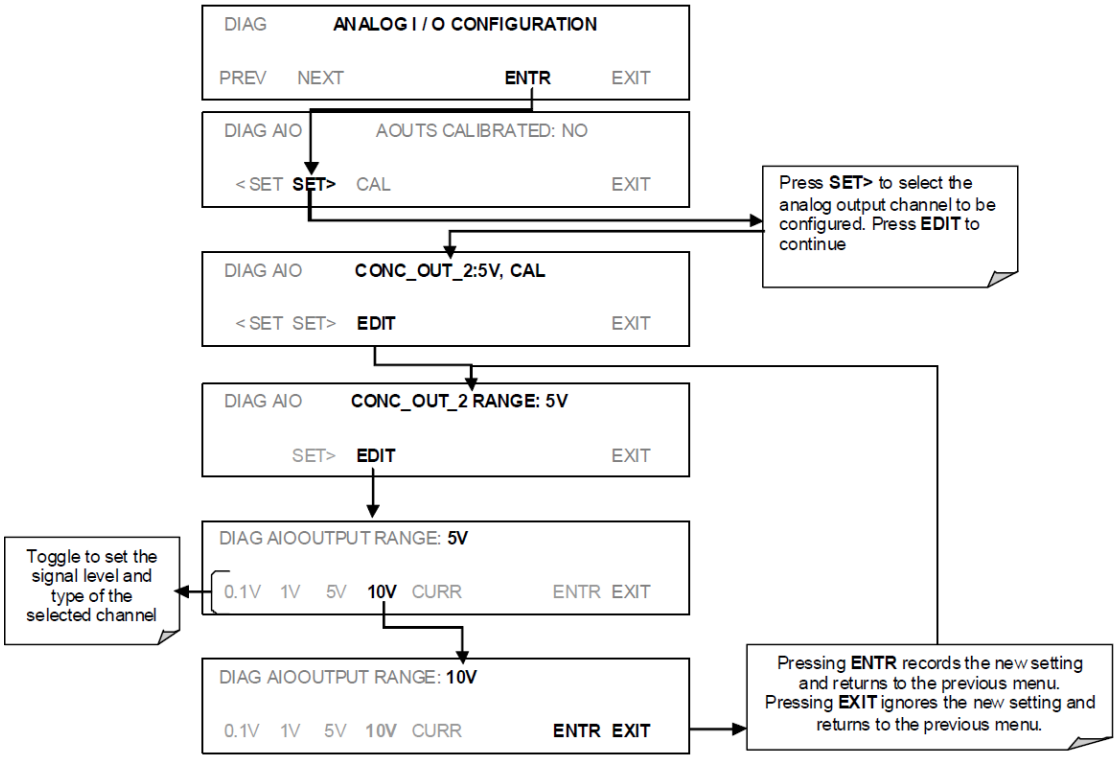

Figure 6.10 Button sequence to set the output signal range.

6.8 Setting the Gas Measurement Mode

If the switching valves software is activated, the T101 can be set to one of three gas measurement modes (Figure 6.11):

6.8.1 H_2S

The sample gas stream is stripped of any ambient SO_2 by a special chemical scrubber, then passed through a catalytic converter that changes the H_2S present into SO_2 which is then measured using the UV fluorescence method

6.8.2 SO_2

The sample gas stream bypasses the SO_2 scrubber and catalytic converter allowing the only ambient SO_2 to be measured.

6.8.3 H_2S – SO_2

The switching valve alternates the gas stream between the two paths at regular intervals allowing the instrument to measure both gases.

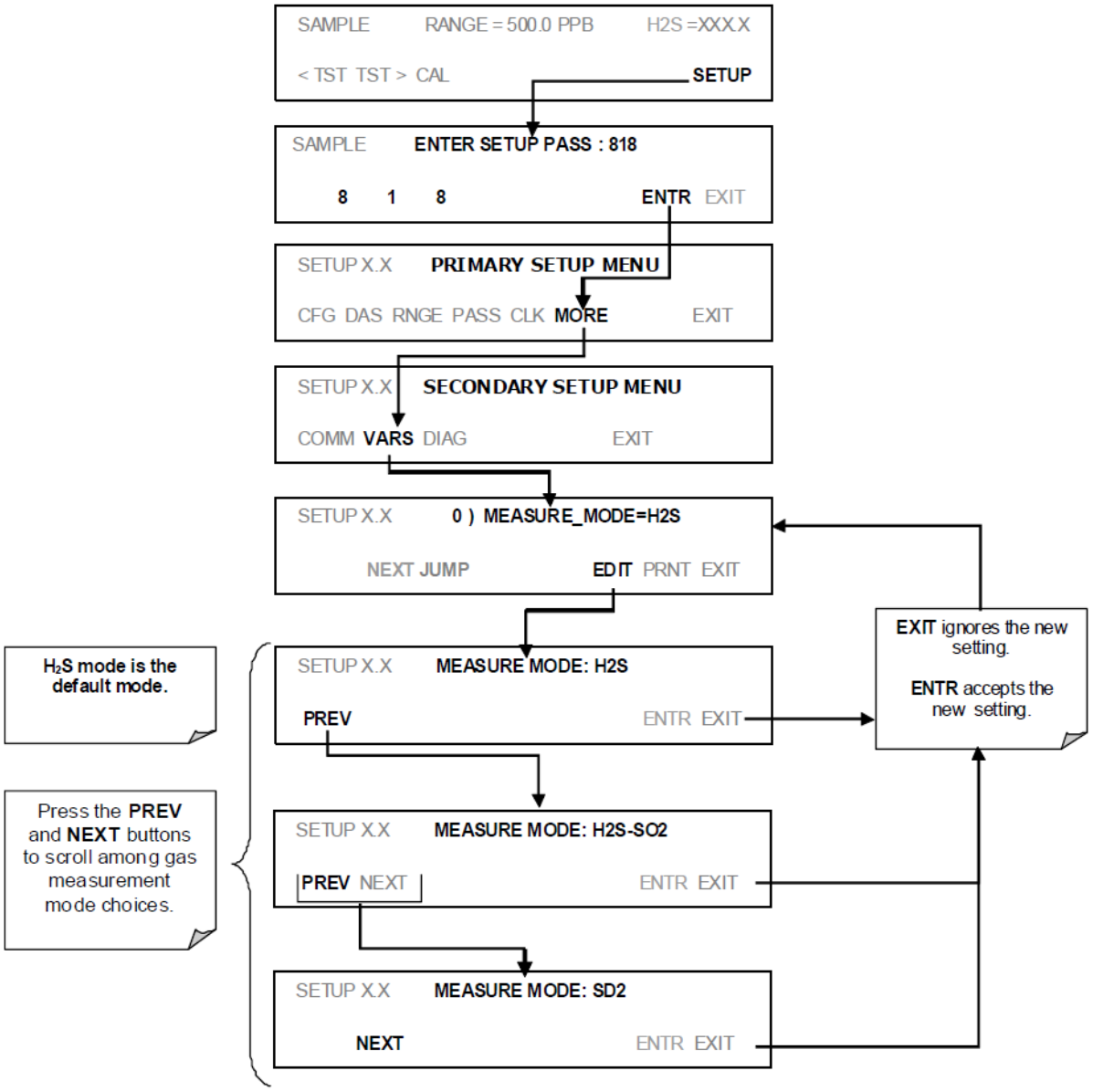

Figure 6.11 Button sequence to change the measurement mode.

6.9 Maintenance Schedule for Quality Control

Table 6.3 shows a typical maintenance schedule for the analyzer. Performing these maintenance regularly ensures the analyzer will continues to operate accurately and reliably over its lifetime.

Table 6.3 Preventive Maintenance Schedule.

ITEM	ACTION	FREQUENCY	CAL CHECK	MANUAL SECTION	DATE PERFORMED						
SO_2 scrubber	Replace	As required	Yes	8.2.3							
$H_2S \rightarrow SO_2$ Converter Catalyst	Replace	As required	Yes	8.5							
[1]Particulate filter	Change particle filter	Weekly	No	8.1							
Verify test functions	Review and evaluate	Weekly	No	Appendix C							
Zero/span check	Evaluate offset and slope	Weekly	--	7.3							
[1]Zero/span calibration	Zero and span calibration	Every 3 months	--	7.2							
[1]External zero air scrubber (optional)	Exchange chemical	Every 3 months	No	see Manual							
[1]Perform flow check	Check Flow	Every 6 Months	No	9.8.2							
[1]Critical flow orifice & sintered filters	Replace	Annually	Yes	7.7							
Internal IZS Permeation Tube	Replace	As required	YES	See manual							
Perform pneumatic leak check	Verify Leak Tight	Annually or after repairs involving pneumatics	Yes	9.8.1							
[2]Pump diaphragm	Replace	At least Every 2 years or if **PRES** is ≥ 33.00 in-Hg-A	Yes	See instruction in diaphragm kit							

PMT sensor hardware calibration	Low-level hardware calibration	On PMT/ preamp changes if 0.7 < **SLOPE** or **SLOPE >**1.3	Yes	See manual							

[1] These Items are required to maintain full warranty; all other items are strongly recommended.
[2] A pump rebuild kit is available from Teledyne API Technical Support including all instructions and required parts (see Appendix B for part numbers).

7.0 Calibration Procedures

7.1 Calibration preparations

Calibration of the Model T101 analyzer requires specific equipment and supplies. These include, but are not limited to, the following:

a. Zero-air source
b. Hydrogen sulfide span gas source
c. Gas lines - all gas line materials should be Teflon-type or glass.
d. A recording device such as a strip-chart recorder and/or data logger (optional).

7.1.1 Zero air: Similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. For H_2S measuring devices, zero air should be a similar composition to the sample gas but devoid of H_2S, hydrocarbons, and SO_2.

7.1.2 Gas Standards: Span gas is specifically mixed to match the chemical composition of the gas being measured at about 90% of the desired full measurement range. For example, if the measurement range is 500 ppb, the span gas should have an H_2S concentration of about 450 ppb.

7.1.3 Calibration gas traceability: All equipment used to produce calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend 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.

7.1.4 Data Recording Devices: A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the T101's serial or analog outputs. If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter. Data recording device should be capable of bi-polar operation so that negative readings can be recorded. For electronic data recording, the T101 provides an internal data acquisition system (DAS), which is described in detail in Section 6.8.

7.2 Manual Calibration

7.2.1 Connect the sources of zero and span gas as shown below. The model 701 zero air generator can be replaced by a zero air cylinder. Figure 7.1 shows

two configuration for the manual calibration setup depending on whether a gas dilution calibrator is used.

7.2.2 Set the expected H_2S span gas concentrations by pressing the button sequence in Figure 7.2. In this example, the instrument is set for single range mode with a reporting range span of 500 ppb.

7.2.3 Perform the zero/span calibration (Figure 7.3). If the ZERO or SPAN buttons are not displayed during the zero and span calibration, the measured concentration value is too different from the expected value and the analyzer does not allow zeroing or spanning the instrument.

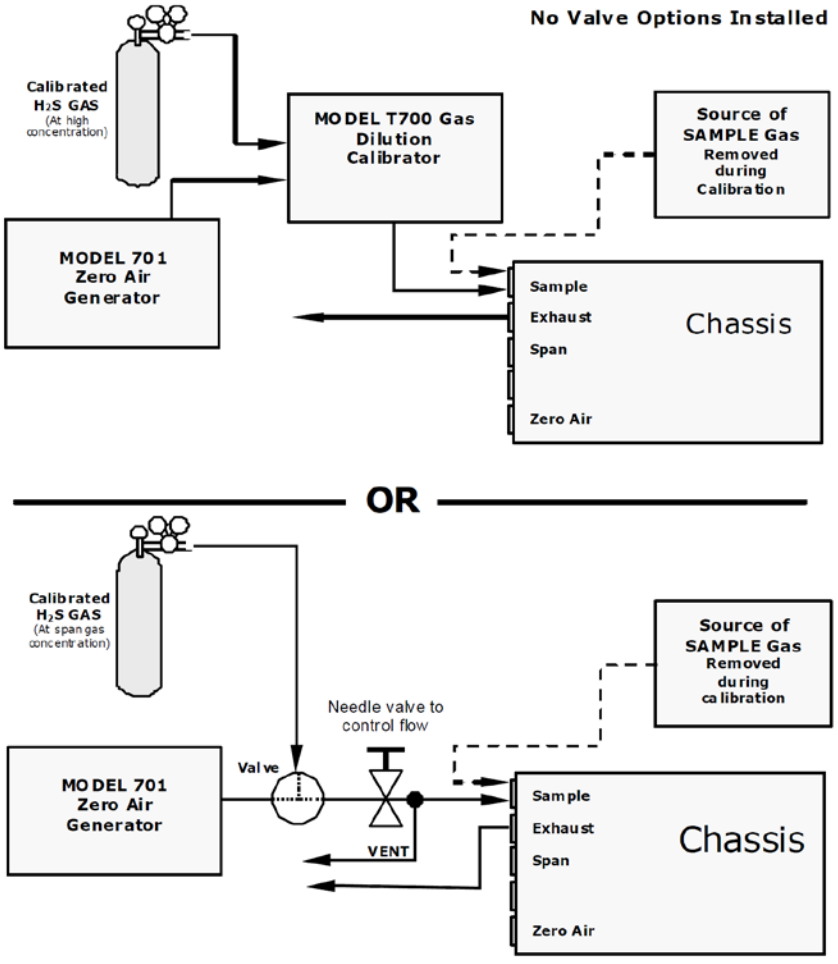

Figure 7.1 Setup for manual calibration

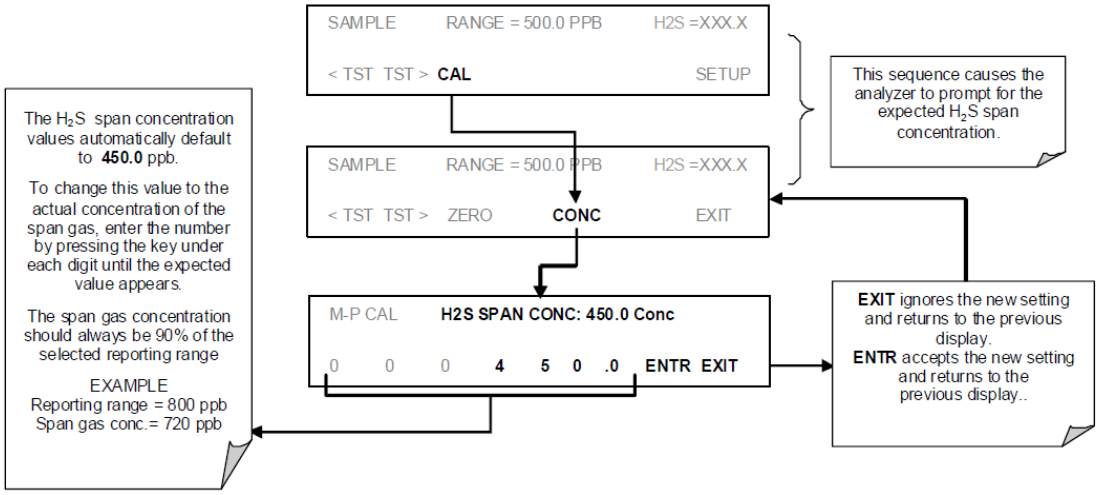

Figure 7.2 Button sequence to set the span gas concentration

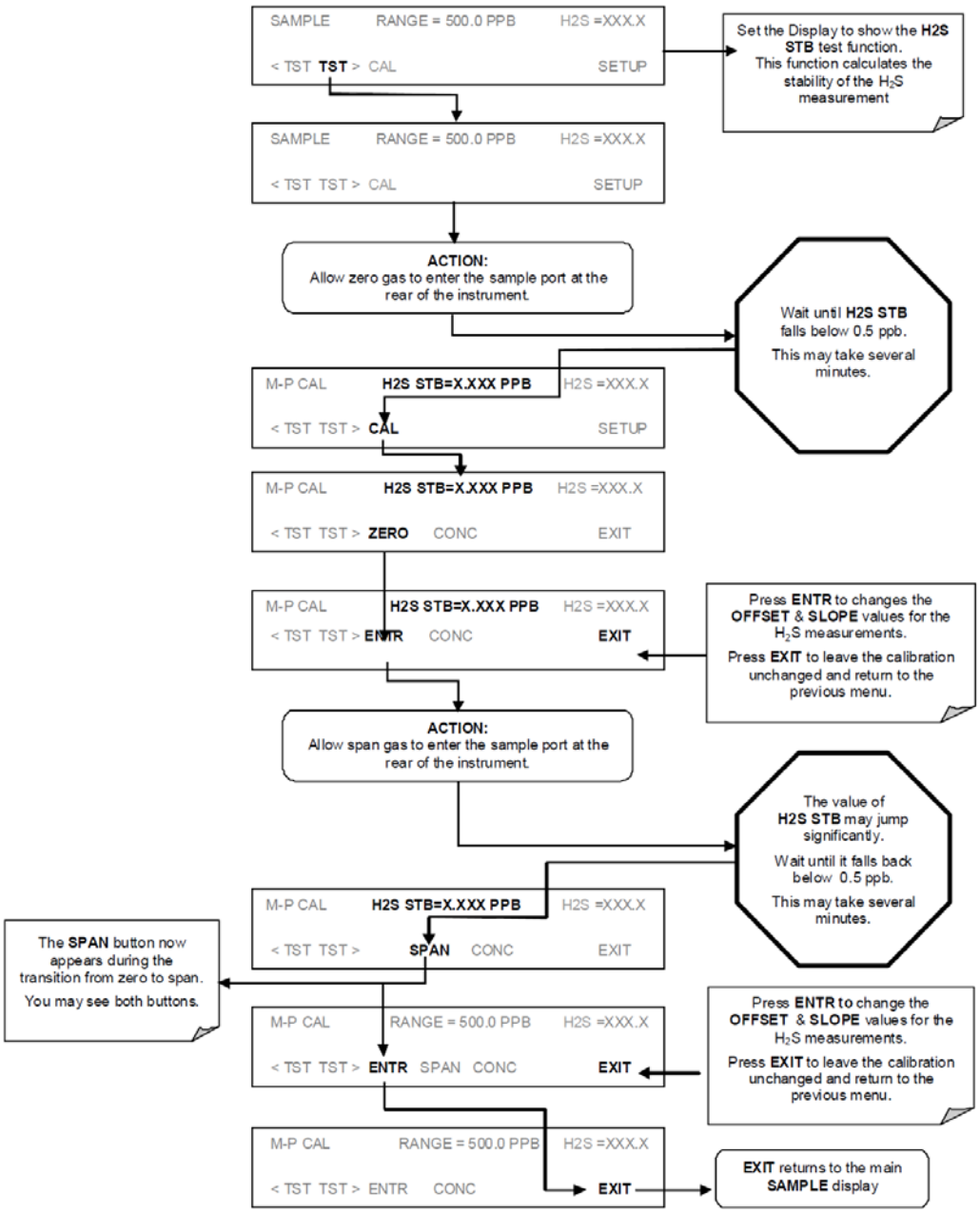

Figure 7.3 Button sequence to carry out ZERO and SPAN calibration.

7.3 Manual Calibration Checks

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

7.3.1 Connect the sources of zero air and span gas as shown in Figure 7.4.

7.3.2 Perform the zero/span calibration check procedure:

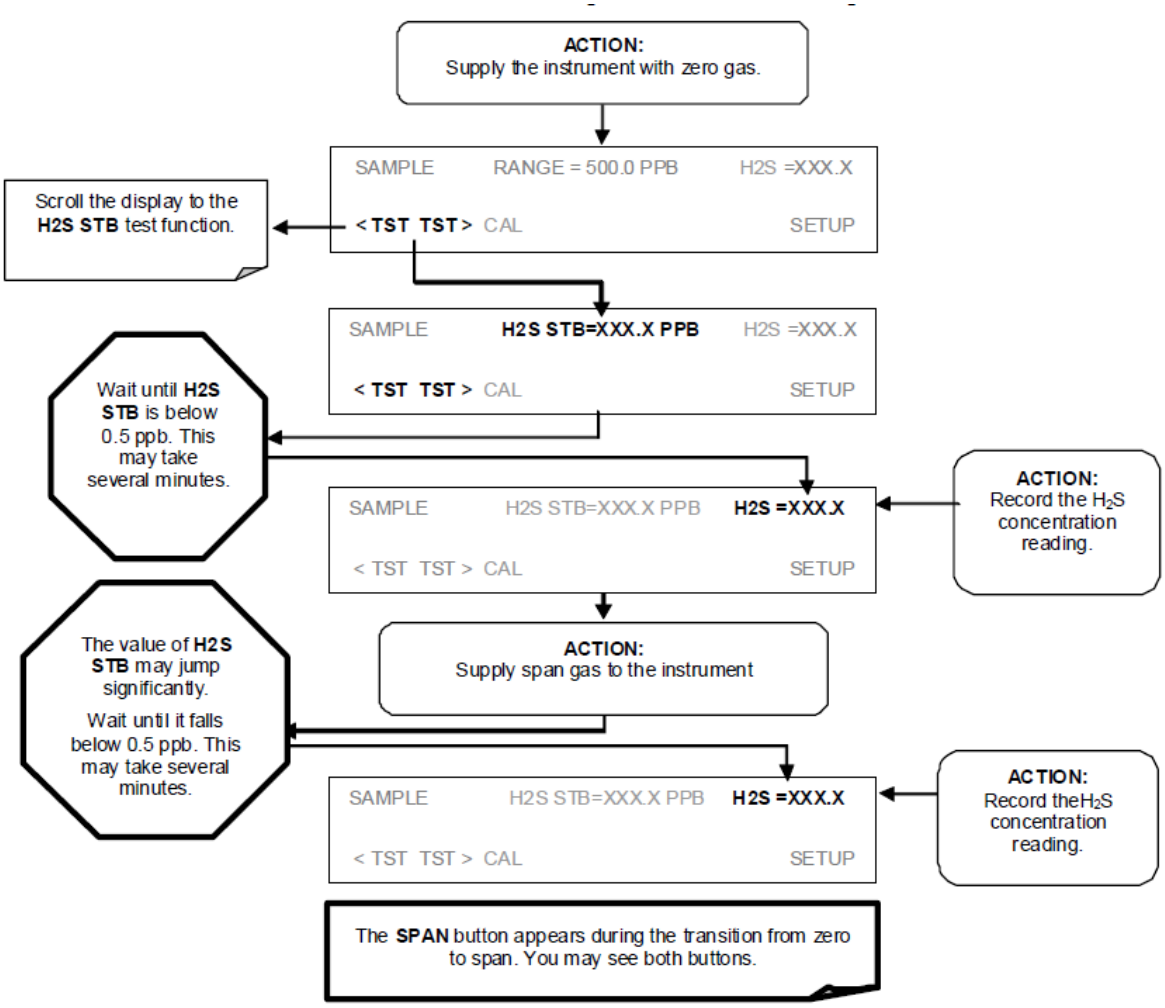

Figure 7.4 Button sequence to carry out a manual calibration check.

7.4 Calibration Quality

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration slope and offset parameters. All parameters must be within parameters listed in Table 7.2.

Table 7.2. Values of H_2S slope and offs

FUNCTION	MINIMUM VALUE	OPTIMUM	MAXIMUM
H_2S SLOPE[1]	-0.700	1.000	1.300
H_2S OFFS[1]	-50.0 mV	<100	250.0 mV
These values should not be significantly different from the values recorded on the Teledyne API *Final Test and Validation Data* sheet that was shipped with your instrument. If they are, refer to the troubleshooting Section 7.			
[1] Shown as they appear when analyzer is in H_2S mode. In SO_2 mode they appear as **SO_2 OFFS** & **SO_2 SLOPE**. In multigas mode, both versions are listed and should be checked			

7.5 Calibration Frequency

7.5.1 To ensure accurate measurements of the H_2S concentrations, calibrate the analyzer at the time of installation, and re-calibrate:

a. No later than three months after the most recent calibration or an acceptable analyzer performance check.
b. An interruption of more than a few days in analyzer operation occurs.
c. Repairs are performed which might affect its calibration.
d. Physical relocation of the analyzer occurs.
e. Any other indication (including excessive zero or span drift) of possible significant inaccuracy of the analyzer.

7.5.2 The zero and span should be checked to determine if a calibration is necessary following any of the activities above.

8.0 Maintenance Procedures

8.1 Changing the sample particulate filter

The particulate filter inside this instrument needs to be changed weekly if no upstream filter is installed. The particulate filter assembly is shown in Figure 8.1.

8.1.1 Turn OFF the analyzer to prevent drawing debris into the sample line.

8.1.2 Open the T101's hinged front panel and unscrew the knurled retaining ring of the filter assembly.

8.1.3 Carefully remove the retaining ring, glass window, PTFE O-ring and filter element.

8.1.4 Replace the filter element, carefully centering it in the bottom of the holder.

8.1.5 Re-install the PTFE O-ring with the notches facing up, the glass cover, then screw on the hold-down ring and hand-tighten the assembly. Inspect the (visible) seal between the edge of the glass window and the O-ring to assure proper gas tightness.

8.1.6 Re-start the analyzer.

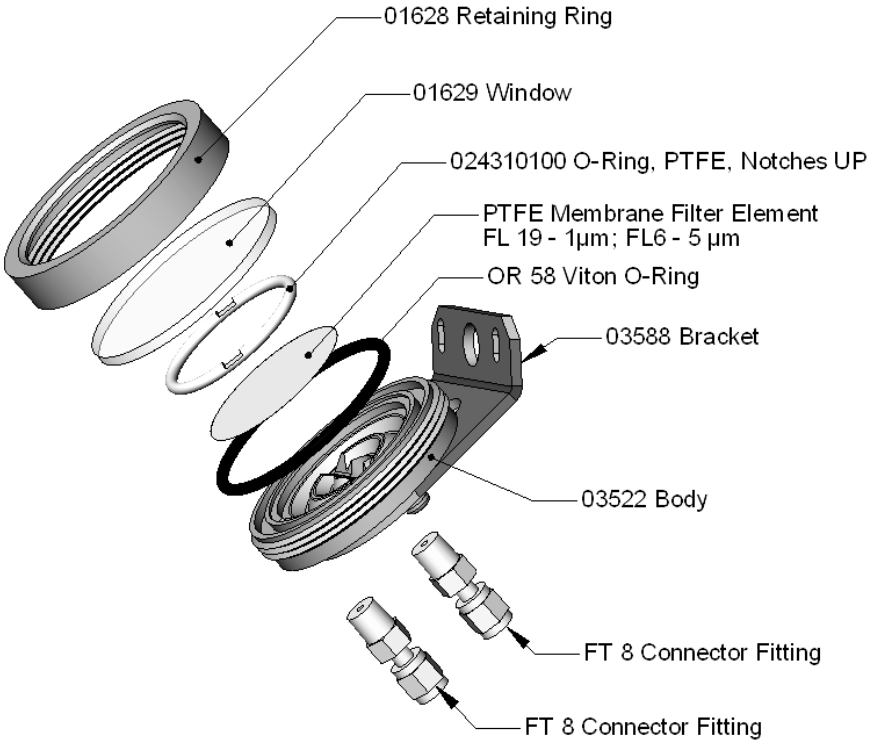

Figure 8.1 Sample particulate filter assembly.

8.2 Maintenance of the SO_2 Scrubber

The SO_2 scrubber of the T101 utilizes a consumable compound to absorb the sample gas SO_2 and must be replaced periodically for accurate and reliable operation.

This material is capable of efficiently scrubbing SO_2 for up to 1000 ppm/hours. This means if the SO_2 content of the sample gas is typically around 100 ppb, the scrubber will function for approximately 10000 hours, a little over 13 months. If, however, the typical ambient SO_2 level of the sample gas is 250 ppb, the scrubber would only last for approximately 4000 hours or about 5 ½ months.

8.2.1 Predicting When the SO_2 scrubber should be replaced

8.2.1.1 Measure the amount of SO_2 in the sample gas.

If your T101 has the multigas measurement options activated, this can be done by following instructions found in Section 4.5.1 and selecting MEASURE MODE = SO_2.

Let the analyzer operate for 30 minutes, then note the SO_2 concentration.

8.2.1.2 Divide 1000 by the SO_2 concentration.

EXAMPLE: If the SO2 concentration is 125 ppb:

Operational hours	=	1000 ppm/hr ÷ 0.125 ppm
Operational hours	=	1,000,000 ppb/hr ÷ 125 ppb
Operational hours	=	8000 hrs

8.2.2 Checking the SO_2 scrubber functionality

Set the analyzer to H_2S measurement mode, then introduce a gas mixture into the sample gas stream that includes at least 20% of the reporting range SO_2. For example, if the analyzer is set for a Single Range & 500 ppb, a concentration of 100 ppb would be appropriate.

An increase of more than 2% in the H_2S reading is an indication that the efficiency of the scrubber is decreasing to the point that the absorbing material should be replaced.

8.2.3 Changing the SO_2 Scrubber Material

8.2.3.1 Input zero air for 5 minutes

8.2.3.2 Turn off analyzer

8.2.3.3 Locates the SO_2 scrubber cartridge in the front of the analyzer, looks like a big white cylinder.

8.2.3.4 Undo the two 1/8 inch fittings on the top of the scrubber

8.2.3.5 Remove the two screws holding the scrubber to the instrument chassis and remove the scrubber

8.2.3.6 Take the two Teflon fitting off the instrument.

8.2.3.7 Empty the SO_2 scrubbing material in to a hazmat bin

8.2.3.8 Fill each side of the scrubber with new SO_2 scrubber material until it is ½ an inch from the bottom of the thread lines so about ½ inches from the top of the scrubber, do not fill it too high or the fitting will crush the material.

8.2.3.9 Remove the Teflon tape from both of the removed fittings, and re-tape them with new Teflon tape.

8.2.3.10 Install both fittings back onto the scrubber.

8.2.3.11 Put the scrubber back into the analyzer and replace the two screws on the bottom.

8.2.3.12 Screw the two 1/8 fittings back onto the top of the scrubber, they can be hooked up either way.

8.2.3.13 Return analyzer to normal operation.

8.3 Maintaining the $H_2S \rightarrow SO_2$ Converter

The catalyst contained in the $H_2S \rightarrow SO_2$ converter of your T101 must be replaced periodically in order for the analyzer to continue measuring H_2S accurately and reliability.

This material is capable of efficiently converting H_2S into SO_2 for up to 6000 ppm/hours. This means if the H_2S content of the sample gas is typically around 600 ppb, the scrubber will function for approximately 10000 hours, a little over 13 months. If, however, the typical ambient H_2S level of the sample gas is 1000 ppb, the scrubber would only last for approximately 6000 hours or about 8 months.

8.3.1 Predicting When the converter catalyst should be replaced

8.3.3.1 Measure the amount of H_2S in the sample gas.

8.3.3.2 Divide 6000 by the H_2S concentration.

EXAMPLE: If the H_2S concentration is 750 ppb:

Operational hours= 6000 ppm/hr ÷ 0.75 ppm

Operational hours= 6,00,000 ppb/hr ÷ 750 ppb

Operational hours= 8000 hrs

8.4 Checking the Efficiency of the $H_2S \rightarrow SO_2$ Converter

8.4.1 Set the analyzer to SO_2 measurement mode (see Section 6.7).

8.4.2 Supply a gas with a known concentration of SO_2 to the sample gas inlet of the analyzer.

8.4.3 Wait until the analyzer's SO_2 concentration measurement stabilizes. This can be determined by setting the analyzer's display to show the SO_2 STB test function SO_2 STB should be 0.5 ppb or less before proceeding.

8.4.4 Record the stable SO_2 concentration.

8.4.5 Set the analyzer to H_2S measurement mode (see Section 6.7).

8.4.6 Supply a gas with a known concentration of H_2S, equal to that of the SO_2 gas used in steps 2-4 above, to the sample gas inlet of the analyzer.

8.4.7 Wait until the analyzer's SO_2 concentration measurement stabilizes. This can be determined by setting the analyzer's display to show the H_2S STB test function H_2S STB should be 0.5 ppb or less before proceeding.

8.4.8 Record the stable H_2S concentration.

8.4.9 Divide the H_2S concentration by the SO_2 concentration.

EXAMPLE: If the SO_2 and H_2S concentration of the two test gases used is 500 ppb:

Measured SO_2 concentration = 499.1 ppb

Measured H_2S concentration = 490.3 ppb

Converter Efficiency = 490.3 ÷ 499.1

Converter Efficiency = 0.982 (98.2%)

8.4.10 It is recommended that the $H_2S \rightarrow SO_2$ converter catalyst material be replaced if the converter efficiency falls below 96% or whatever efficiency rating is specified by local regulatory requirements.

8.4 Changing the $H_2S \rightarrow SO_2$ Converter Catalyst Material

The $H_2S \rightarrow SO_2$ converter is located in the center of the instrument, see Figure 8.2 for the assembly. The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple can be reused.

8.4.1 Turn off the analyzer power, remove the cover and allow the converter to cool.

8.4.2 Remove the top lid of the converter as well as the top layers of the insulation until the converter cartridge can be seen.

8.4.3 Remove the tube fittings from the converter.

8.4.4 Disconnect the power and the thermocouple of the converter. Unscrew the grounding clamp of the power leads with a Phillips-head screw driver.

8.4.5 Remove the converter assembly (cartridge and band heater) from the can. Make a note of the orientation of the tubes relative to the heater cartridge.

8.4.6 Unscrew the band heater and loosen it, take out the old converter cartridge.

8.4.7 Wrap the band heater around the new replacement cartridge and tighten the screws using a high-temperature anti-seize agent such as copper paste. Make sure to use proper alignment of the heater with respect to the converter tubes.

8.4.8 Replace the converter assembly, route the cables through the holes in the housing and reconnect them properly. Reconnect the grounding clamp around the heater leads for safe operation.

8.4.9 Re-attach the tube fittings to the converter and replace the insulation and cover.

8.4.10 Replace the instrument cover and power up the analyzer.

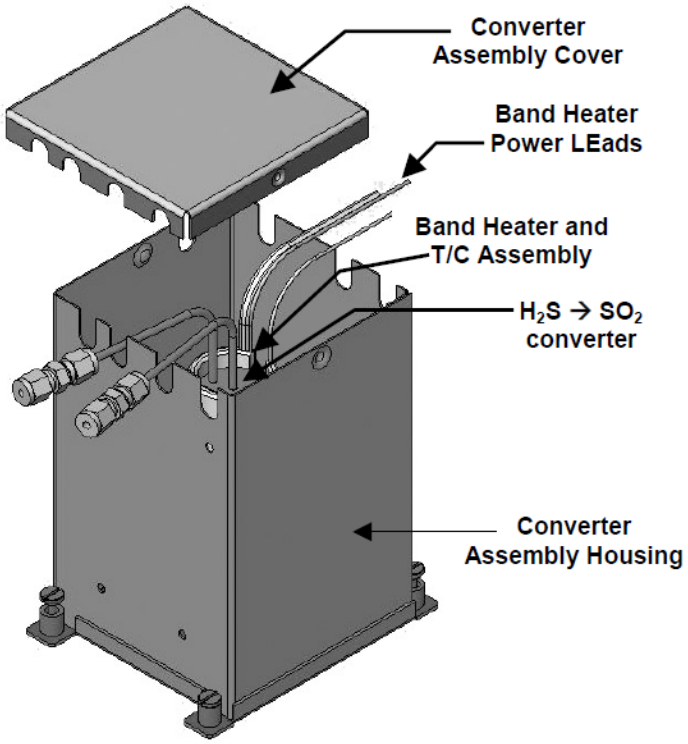

Figure 8.2 $H_2S \rightarrow SO_2$ converter.

8.4 Checking for Light Leaks

8.4.1 Scroll the TEST functions to PMT.

8.4.2 Supply zero gas to the analyzer.

8.4.3 With the instrument still running, carefully remove the analyzer cover. Take extra care not to touch any of the inside wiring with the metal cover or your body. Do not drop screws or tools into a running analyzer!

8.4.4 Shine a powerful light at the inlet and outlet fittings, at all of the joints of the sample chamber, and around the PMT housing. The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise.

8.4.5 If there is a PMT response to the external light, symmetrically tighten the sample chamber mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent). Often, light leaks are also caused by O-rings being left out of the assembly.

8.4.6 Carefully replace the analyzer cover.

8.4.7 If tubing or O-rings were changed, carry out a leak check (Section 9.8).

8.4 Changing the Critical Flow Orifice.

This device can clog, despite the fact this device is protected by sintered stainless steel filters, particularly if the instrument is operated without a sample filter or in an environment with very fine, sub-micron particle-size dust.

8.4.1 Turn off power to the instrument and vacuum pump.
8.4.2 Locate the critical flow orifice on the pressure sensor assembly (Figure 8.3).
8.4.3 Disconnect the pneumatic line.
8.4.4 Unscrew the NPT fitting.
8.4.5 Take out the components of the assembly: a spring, a sintered filter, two O-rings and the critical flow orifice. You may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.
8.4.6 Discard the two O-rings and the sintered filter.
8.4.7 Replace the critical flow orifice.
8.4.8 Let the part dry.
8.4.9 Re-assemble the parts using a new filter and o- rings.
8.4.10 Reinstall the NPT fitting and connect all tubing.
8.4.11 Power up the analyzer and allow it to warm up for 60 minutes.
8.4.12 Perform a leak check (refer to Section 9.8).

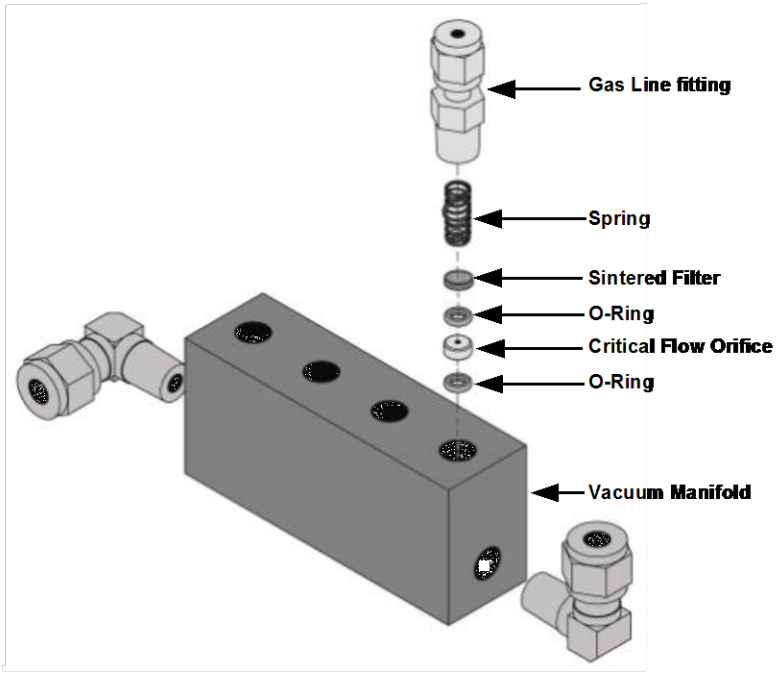

Figure 8.3 Critical flow orifice assembly

9.0 Troubleshooting and Service

9.1 Fault Diagnosis with Warning Messages

9.1.1 The most common and/or serious instrument failures will result in a warning message displayed on the front panel. Table 9.1 contains a list of warning messages, along with a list of possible faults that might be responsible for the warning condition.

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

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

Table 9.1. Warning Messages - Indicated Failures

WARNING MESSAGE	FAULT CONDITION	POSSIBLE CAUSES
ANALOG CAL WARNING	The instrument's A/D circuitry or one of its analog outputs is not calibrated	A parameter for one of the analog outputs has been changed and the calibration routine was not re-run A/D circuitry failure on motherboard Other motherboard electronic failure
BOX TEMP WARNING	Box Temp is < 5 °C or > 48 °C.	NOTE: Box temperature typically runs ~7°C warmer than ambient temperature. Poor/blocked ventilation to the analyzer. Stopped Exhaust fan. Ambient temperature outside of specified range
CANNOT DYN SPAN	Dynamic Span operation failed	Measured concentration value is too high or low. Concentration slope value to high or too low
CANNOT DYN ZERO	Dynamic Zero operation failed	Measured concentration value is too high. Concentration offset value to high.

CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	Failed disk on module User erased data
CONV TEMP WARNING	The temperature of the H2S→SO2 catalytic converter is outside its optimal operating range.	Bad converter heater Bad converter temperature sensor Bad relay controlling the converter heater. Entire relay board is malfunctioning I2C buss malfunction
DARK CAL WARNING	The Dark Cal signal is higher than 100 mV.	Light leak in reaction cell Shutter solenoid is not functioning Failed relay board I2C bus failure Loose connector/wiring PMT preamp board bad or out of calibration
DATA INITIALIZED	Data Storage in DAS was erased	Failed disk on module User cleared data
HVPS WARNING	High voltage power supply output is <400 V or >900 V	High voltage power supply is bad High voltage power supply is out of cal A/D converter circuitry is bad

WARNING MESSAGE	**FAULT CONDITION**	**POSSIBLE CAUSES**
IZS TEMP WARNING	On units with IZS options installed: The permeation tube temperature is Sample chamber temperature is < 45°C or > 55°C	Bad IZS heater Bad IZS temperature sensor Bad relay controlling the IZS heater Entire relay board is malfunctioning I^2C buss malfunction Failure of thermistor interface circuitry on motherboard
PMT DET WARNING	PMT detector output is > 4995 mV	Failed PMT Malfunctioning PMR preamp board A/D converter circuitry failure

WARNING MESSAGE	FAULT CONDITION	POSSIBLE CAUSES
PMT TEMP WARNING	PMT temperature is Sample chamber temperature is < 2°C or > 12°C	Bad PMT thermo-electric cooler Failed PMT TEC driver circuit Bad PMT preamp board Failed PMT temperature sensor Loose wiring between PMT temperature sensor and PMT Preamp board Malfunction of analog sensor input circuitry on motherboard
RCELL TEMP WARNING	Sample chamber temperature is < 45°C or > 55°C	Bad reaction cell heater Bad reaction cell temperature sensor Bad relay controlling the reaction cell heater Entire relay board is malfunctioning I^2C buss malfunction
Warning Message	Fault Condition	Possible Causes
REAR BOARD NOT DET	Mother Board not detected on power up.	Warning only appears on serial I/O com port(s) Front panel display will be frozen, blank or will not respond. Massive failure of mother board.
Relay BOARD WARN	The CPU cannot communicate with the Relay Board.	I^2C buss failure Failed relay board Loose connectors/wiring
SAMPLE FLOW WARN	Sample flow rate is < 500 cc/min or > 1000 cc/min.	Failed sample pump Blocked sample inlet/gas line Dirty particulate filter Leak downstream of critical flow orifice Failed flow sensor/circuitry
SAMPLE PRES WARN	Sample Pressure is <10 in-Hg or > 35 in-Hg1	If sample pressure is < 10 in-hg: Blocked particulate filter Blocked sample inlet/gas line Failed pressure sensor/circuitry If sample pressure is > 35 in-hg: Blocked vent line on pressurized sample/zero/span gas supply Bad pressure sensor/circuitry
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

WARNING MESSAGE	FAULT CONDITION	POSSIBLE CAUSES
UV LAMP WARNING	The UV lamp intensity is < 600mV or > 4995 mV	UV lamp is bad Reference detector is bad Motherboard analog sensor input circuitry has failed. Fogged or damaged lenses/filters in UV light path A/D converter circuitry failure
[1] Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg		

9.2 Fault Diagnosis with test functions

9.2.1 The TEST functions, viewable from the front panel, can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer's theory of operation. We recommend use of the APICOM remote control program to download, graph and archive TEST data for analysis, and long-term monitoring of diagnostic data.

9.2.2 The acceptable ranges for these test functions are listed in Appendix A. The original values for these test functions on checkout at the factory are listed in the Final Test and Validation Data Sheet, which was shipped with the instrument. Values outside the acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions with values that are within the acceptable range, but have significantly changed from the measurements recorded on the factory data sheet, may also indicate a failure or a maintenance item.

9.2.3 A problem report worksheet has been provided in Appendix C to assist in recording the value of these test functions. Table 9.2 contains more common causes for these values to be out of range.

Table 9.2. Test Functions - Possible Causes for Out-Of-Range Values

TEST FUNCTION	INDICATED FAILURE(S)
H_2S STB[1]	Unstable concentrations; leaks
SAMPLE FL	Leaks; clogged critical flow orifice
PMT	Calibration error; HVPS problem; PMT problem; No flow (leaks)
NORM PMT	Calibration error; HVPS problem; PMT problem
HVPS	HVPS broken; preamp board circuit problems
RCELL TEMP	Malfunctioning heater; relay board communication (I2C bus); relay burnt out

BOX TEMP	Environment out of temperature operating range; broken thermistor; runaway heater
PMT TEMP	TEC cooling circuit broken; High chassis temperature; 12V power supply
IZS TEMP (OPTION)	Malfunctioning heater; relay board communication (I2C bus); relay burnt out
CONV TEMP	Malfunctioning heater or temperature sensor; relay board communication (I2C bus); relay burnt out
PRESS	Leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure;
H_2S SLOPE[1]	Calibration error; span gas concentration incorrect; leaks; low lamp output
H_2S OFFS[1]	Incorrect span gas concentration/contaminated zero air/leak; low- level calibration off
TIME OF DAY	Internal clock drifting; move across time zones; daylight savings time?

[1] Shown as they appear when analyzer is in H_2S mode. In SO_2 mode appear as **SO_2 STB**, **SO_2 OFFS** & **SO_2 SLOPE.** In multigas mode, both versions appear.

9.3 Gas Flow Problem

9.3.1 Zero or Low Sample flow. If the pump is operating but the unit reports a 0 gas flow, do the following three steps:

9.3.1.1 Check for actual sample flow

9.3.1.2 Check pressure

9.3.1.3 Carry out a leak check

9.3.2 To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument. Make sure that the unit is in basic SAMPLE mode. Place a finger over the inlet and see if it gets sucked in by the vacuum or, more properly, use a flow meter to measure the actual flow. If there is proper flow of around 550-650 cm^3/min, contact Technical Support. If there is no flow or low flow, continue with the next step.

9.3.3 Check that the sample pressure is at or around 26 in-Hg-A (about 1" below ambient atmospheric pressure).

9.4 High flow

9.4.1 Flows that are significantly higher than the allowed operating range (typically ±10% of the nominal flow) should not occur in the T101 unless a pressurized sample, zero or span gas is supplied to the inlet ports. Be sure to vent excess pressure and flow just before the analyzer inlet ports.

9.4.2 When supplying sample, zero or span gas at ambient pressure, a high flow would indicate that one or more of the critical flow orifices are physically broken (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications. If the flows >15% higher than normal, we recommend that the technician re-calibrate the flow electronically using the procedure in Teledyne Operation Manual (Section 4.6.8), followed by a thorough and regular monitoring of these flows to see if the new setting is retained properly.

9.5 Calibration Problems

9.5.1 Negative concentrations

9.5.1.1 A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero-calibration point. This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -20 ppb, but should alternate with similarly high, positive values.

9.5.1.2 Mis-calibration is the most likely explanation for negative concentration values. If the zero air contained some H_2S gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as "zero", the analyzer may report negative values when measuring air that contains little or no H_2S. The same problem occurs, if the analyzer was zero-calibrated using ambient air or span gas.

9.5.1.3 If the response offset test function for H_2S (H_2S OFFS) are greater than 150 mV, a failed PMT or high voltage supply, or sample chamber contamination, could be the cause.

9.5.2 No Response

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

9.5.2.1 Confirm response by supplying H_2S span gas of about 80% of the range value to the analyzer.

9.5.2.2 Check the sample flow rate for proper value.

9.5.2.3 Check for disconnected cables to the sensor module.

9.5.2.4 Carry out an electrical test with the ELECTRICAL TEST (ETEST) procedure in the diagnostics menu.

9.5.2.5 Carry out an optical test using the OPTIC TEST (OTEST) procedure in the diagnostics menu, see Section 4.6.4 in the Manufacture operation manual. If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly. If the T101 passes both ETEST and OTEST, the instrument is capable of detecting light and processing the signal to produce a reading. Therefore, the problem must be in the pneumatics, optics or the UV lamp/lamp driver.

9.5.3 Unstable zero and span

9.5.3.1 Leaks in the T101 or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

9.5.3.2 Check for leaks in the pneumatic systems as described in Section 9.8. Consider pneumatic components in the gas delivery system outside the T101 such as a change in zero air source (ambient air leaking into zero air-line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.

9.5.3.3 Once the instrument passes a leak check, do a flow check to make sure that the instrument is supplied with adequate sample gas.

9.5.3.4 Confirm the UV lamp, sample pressure and sample temperature readings are correct and steady.

9.5.3.5 Verify that the sample filter element is clean and does not need to be replaced.

9.5.4 Inability to span-No span button

Generally, the T101 will not display certain keyboard choices whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a SPAN button when carrying out a span calibration, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

9.5.4.1 Verify the expected concentration is set to the actual span gas concentration in the CONC sub-menu.

9.5.4.2 Confirm that the H_2S span gas source is accurate. This can be done by comparing the source with another calibrated analyzer, or by having the H_2S source verified by an independent traceable photometer.

9.5.4.3 Check for leaks in the pneumatic systems as described in Section 9.8. Leaks can dilute the span gas and the measured analyzer concentration may fall short of the expected concentration defined in the CONC sub-menu.

9.5.4.4 If the physical, low-level calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values. One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 to 150 for offsets). See Section 9.6.4 in the Manufacture Manual for how to carry out a low-level hardware calibration.

9.5.5 Inability to Zero-No Zero Button

In general, the T101 will not display certain keyboard choices whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a ZERO button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

9.5.5.1 Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to an external zero air source using H_2S and SO_2 free air. Check the zero air scrubber for performance. It may need to be replaced.

9.5.5.2 Check to make sure that there is no ambient air leaking into the zero air line. Check for leaks in the pneumatic systems as described in Section 9.8.

9.5.6 Non-linear Response

The T101 was factory calibrated to a high level of H_2S and should be linear to within 1% of full scale. Common causes for non-linearity are:

9.5.6.1 Leaks in the pneumatic system. Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed. Check for leaks as described in Section 9.8.

9.5.6.2 The calibration device is in error. Check flow rates and concentrations, particularly when using low concentrations. If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.

9.5.6.3 The standard gases may be mislabeled as to type or concentration. Labeled concentrations may be outside the certified tolerance.

9.5.6.4 The sample delivery system may be contaminated. Check for dirt in the sample lines or sample chamber.

9.5.6.5 Calibration gas source may be contaminated.

9.5.6.6 Dilution air contains sample or span gas.

9.5.6.7 Sample inlet may be contaminated with H_2S exhaust from this or other analyzers. Verify proper venting of the pump exhaust.

9.5.6.8 Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port. Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line. Make sure to create and properly vent excess span gas.

9.5.6.9 If the instrument is equipped with an intern IZS valve option and the H_2S span value is continuously trending downward, the IZS permeation tube may require replacement.

9.6 Discrepancy between analog output and display

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

9.7 Other performance problems

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

9.7.1 Excessive Noise

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

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

9.7.2 Slow Response

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

9.7.2.1 Dirty or plugged sample filter or sample lines.

9.7.2.2 Sample inlet line is too long.

9.7.2.3 Dirty or plugged critical flow orifices. Check flows (Section 9.8.2), pressures (Section 9.8.1) and, if necessary, change the critical flow orifice (Section 8.7).

9.7.2.4 Wrong materials in contact with sample - use Teflon materials only.

9.7.2.5 Sample vent line is located too far from the instrument sample inlet and causes long mixing and purge times. Locate sample inlet (overflow) vent as close as possible to the analyzer's sample inlet port.

9.7.2.6 Dirty sample chamber. Clean the sample chamber.

9.7.2.7 Insufficient time allowed for purging of lines upstream of the analyzer.

9.7.2.8 Insufficient time allowed for H_2S calibration gas source to become stable.

9.8 Subsystem Checkout

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

9.8.1 Detail Pressure Leak Check

Obtain a leak checker similar to Teledyne API's part number 01960, which contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two stage regulator adjusted to ≤ 15 psi, a shutoff valve and pressure gauge may be used.

9.8.1.1 Turn OFF power to the instrument and remove the instrument cover.

9.8.1.2 Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.

9.8.1.3 Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice. Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles. Once the fittings have been wetted with soap solution, do not re-apply vacuum as it will draw soap solution into the instrument and contaminate it. Do not exceed 15 psi pressure.

9.8.1.4 If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked. Connect the leak checker to the normally closed ports and check with soap bubble solution.

9.8.1.5 If the analyzer is equipped with an IZS Option, connect the leak checker to the Dry Air inlet and check with soap bubble solution.

9.8.1.6 Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.

9.8.1.7 Clean soap solution from all surfaces, re-connect the sample and exhaust lines, and replace the instrument cover. Restart the analyzer.

9.8.2 Performing a Sample Flow Check

9.8.2.1 Use a separate calibrated flow meter capable of measuring flows between 0 and 1000 cm^3/min to measure the gas flow rate though the analyzer. Do not use the built in flow measurement viewable from the front panel of the instrument.

9.8.2.2 Sample flow checks are useful for monitoring the actual flow of the instrument, to monitor drift of the internal flow measurement. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. To perform a sample flow check:

9.8.2.2.1 Disconnect the sample inlet tubing from the rear panel SAMPLE port shown in Figure 6.1.

9.8.2.2.2 Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.

9.8.2.2.3 The sample flow measured with the external flow meter should be 600 cm^3/min ± 75 cm^3/min. If a combined sample/ozone air Perma Pure dryer is installed (optional equipment), the flow will be 740 cm^3/min ± 10% (600 cm^3/min for the sample and 140 cm^3/min for the ozone generator supply air).

9.8.2.2.4 Low flows indicate blockage somewhere in the pneumatic pathway.

Appendices

Appendix A: Test Measurements

TEST Measurement	Message Text	DESCRIPTION
RANGE	RANGE=500.0 PPB [3]	D/A range in single or auto-range modes.
RANGE1	RANGE1=500.0 PPB [3]	D/A #1 range in independent range mode.
RANGE2	RANGE2=500.0 PPB [3]	D/A #2 range in independent range mode.
RANGE3 [5]	RANGE3=500.0 PPB [3]	D/A #3 range in independent range mode.
STABILITY	SO2 STB=11.4 PPB [3]	Concentration stability #1.
STABILITY2 [8]	SO2 STB2=6.3 PPB [3]	Concentration stability #2.
RESPONSE [2]	RSP=1.11(0.00) SEC	Instrument response. Length of each signal processing loop. Time in parenthesis is standard deviation.
OXYFLOW [6]	OXY FLOW=150 CC/M	Oxygenator flow rate
SAMPFLOW	SAMP FL=700 CC/M	Sample flow rate.
SAMPPRESS	PRES=29.9 IN-HG-A	Sample pressure.
PMTDET	PMT=762.5 MV	Raw PMT reading.
NORMPMTDET	NORM PMT=742.9 MV	PMT reading normalized for temperature, pressure, auto-zero offset, but not range.
UVDET	UV LAMP=3457.6 MV	UV lamp reading.
STABILITYUV [9]	UV STB=5.607 MV	UV lamp stability reading.
LAMPRATIO	LAMP RATIO=100.0 %	UV lamp ratio of current reading divided by calibrated reading.
STRAYLIGHT	STR. LGT=0.1 PPB	Stray light offset.
DARKPMT	DRK PMT=19.6 MV	PMT dark offset.
DARKLAMP	DRK LMP=42.4 MV	UV lamp dark offset.
SO2SLOPE	SO2 SLOPE=1.000	Slope for current range, computed during zero/span calibration.
SO2OFFSET	SO2 OFFS=0.0 MV	Offset for current range, computed during zero/span calibration.
H2SSLOPE	H2S SLOPE=1.000	Slope for current range, computed during zero/span calibration.
H2SOFFSET	H2S OFFS=0.0 MV	Offset for current range, computed during zero/span calibration.
TRSSLOPE [5]	TRS SLOPE=1.000	Slope for current range, computed during zero/span calibration.
TRSOFFSET [5]	TRS OFFS=0.0 MV	Offset for current range, computed during zero/span calibration.

HVPS	HVPS=650 VOLTS	High voltage power supply output.
RCELLDUTY [2]	RCELL ON=0.00 SEC	Reaction cell temperature control duty cycle.
RCELLTEMP	RCELL TEMP=52.1 C	Reaction cell temperature.
BOXTEMP	BOX TEMP=35.5 C	Internal chassis temperature.
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
IZSDUTY 2	IZS ON=0.00 SEC	IZS temperature control duty cycle.
IZSTEMP	IZS TEMP=52.2 C	IZS temperature.
CONVTEMP 4	CONV TEMP=315.0 C	Converter temperature.
SO2	SO2=261.4 PPB	SO2 concentration for current range.
H2S/TRS	H2S/TRS=331.6 PPB	H2S/TRS concentration for current
TRS 5	TRS=378.4 PPB	TRS concentration for current range.
TESTCHAN	TEST=3721.1 MV	Value output to TEST_OUTPUT analog
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.

[1] The name is used to request a message via the RS-232 interface, as in “T BOXTEMP”.

[2] Engineering software.

[3] Current instrument units.

[4] T101, M101E.

[5] Triple-gas option.

[6] T108, M108E.

[7] Concentration alarm option.

[8] T108U, M108EU.

[9] Optional.

Appendix B Spare parts

PARTNUMBER	DESCRIPTION
000940100	CD, ORIFICE, .003 GREEN
000940400	CD, ORIFICE, .004 BLUE
000940800	CD, ORIFICE, .012 (NO PAINT)
002690000	CD, LENS, PL-CON (KB)
002700000	CD, LENS, BI-CON (KB)
002720000	CD, FILTER, 330NM (KB)
003290000	THERMISTOR, BASIC (VENDOR ASSY)(KB)
005960000	AKIT, EXP, 6LBS ACT CHARCOAL (2 BT=1)
009690000	AKIT, TFE FLTR ELEM (FL6 100=1) 47mm
009690100	AKIT, TFE FLTR ELEM (FL6, 30=1) 47mm
011630000	HVPS INSULATOR GASKET (KB)
012720000	ASSY, CELL ADAPTOR, (KB)
013140000	ASSY, COOLER FAN (NOX/SOX)
013210000	ASSY, VACUUM MANIFOLD
013390000	ASSY, KICKER
013400000	CD, PMT, SO2, (KB)
013420000	ASSY, ROTARY SOLENOID
013570000	THERMISTOR HOUSING ASSY SOX/NOX(KB)
014080100	ASSY, HVPS, SOX/NOX
014400100	OPTION, ZERO AIR SCRUBBER
014750000	AKIT, EXP KIT, IZS
016290000	WINDOW, SAMPLE FILTER, 47MM (KB)
016300700	ASSY, SAMPLE FILTER, 47MM, ANG BKT
037860000	ORING, TEFLON, RETAINING RING, 47MM (KB)
040010000	ASSY, FAN REAR PANEL
040030100	PCA, PRESS SENSORS (1X), w/FM4
041020000	ASSY, MOLY CONV, WELD, (KB)
041620100	ASSY, SO2 SENSOR (KB)

041800400	PCA, PMT PREAMP, VR
042410200	ASSY, PUMP, INT, SOX/O3/IR *
043570000	AKIT, EXPENDABLES
045230200	PCA, RELAY CARD
046250000	ASSY, RXCELL HEATER/FUSE
046260000	ASSY, THERMISTOR, RXCELL (KB)
046880000	ASSY, SO2 SCRUBBER, PTFE CARTRIDGE
048830000	AKIT, EXP KIT, EXHAUST CLNSR, SILCA GEL
049310100	PCA,TEC DRIVER,PMT,(KB)
049760100	ASSY, TC PROG PLUG, MINI HICON, 'K', TC1
050510200	PUMP, INT, 115/240V * (KB)
050610100	OPTION, 100-120V/60Hz (KB)
050610200	OPTION, 100-120V/50Hz (KB)
050610300	OPTION, 220-240V/50Hz, (KB)
050610400	OPTION, 220-240V/60Hz (KB)
050630100	PCA, REF DET w/OP20, DUAL OUT
051990000	ASSY, SCRUBBER, INLINE EXHAUST, DISPOS
052660000	ASSY, HEATER/THERM, IZS
052930200	ASSY, BAND HEATER TYPE K, NOX
055100200	ASSY, OPTION, PUMP, 240V *
055560000	ASSY, VALVE, VA59 W/DIODE, 5" LEADS
058021100	PCA, MOTHERBD, GEN 5-ICOP
061930000	PCA, UV LAMP DRIVER, GEN-2 43mA *
062390000	ASSY, MOLY GUTS w/WOOL
066970000	PCA, INTRF. LCD TOUCH SCRN, F/P
067240000	CPU, PC-104, VSX-6154E, ICOP *
067300000	PCA, AUX-I/O BD, ETHERNET, ANALOG & USB
067300100	PCA, AUX-I/O BOARD, ETHERNET
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067900000	LCD MODULE, W/TOUCHSCREEN(KB)
068810000	PCA, LVDS TRANSMITTER BOARD

069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
072660000	MANUAL, T101, OPERATORS
073480100	DOM, w/SOFTWARE, T101 *
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	PLUG, 12, MC 1.5/12-ST 3.81 (KB)
CN0000520	PLUG, 10, MC 1.5/10-ST-3.81 (KB)
FL0000001	FILTER, SS (KB)
FL0000003	FILTER, DFU (KB)
FM0000004	FLOWMETER (KB)
HW0000005	FOOT
HW0000020	SPRING
HW0000030	ISOLATOR
HW0000031	FERRULE, SHOCKMOUNT
HW0000036	TFE TAPE, 1/4" (48 FT/ROLL)
HW0000101	ISOLATOR
HW0000453	SUPPORT, CIRCUIT BD, 3/16" ICOP
HW0000685	LATCH, MAGNETIC, FRONT PANEL
KIT000093	AKIT, REPLCMNT(3187)214NM FLTR (BF)
KIT000095	AKIT, REPLACEMENT COOLER
KIT000207	KIT, RELAY RETROFIT
KIT000219	AKIT, 4-20MA CURRENT OUTPUT
KIT000236	KIT, UV LAMP, w/ADAPTER (BIR)
KIT000253	ASSY & TEST, SPARE PS37
KIT000254	ASSY & TEST, SPARE PS38
KIT000261	AKIT, SOX SCRUBBER MATERIAL (CH17), 1oz
OP0000031	WINDOW, QUARTZ, 1/2"DIA, .063" THICK (KB
OR0000001	ORING, 2-006VT *(KB)
OR0000004	ORING, 2-029V
OR0000006	ORING, 2-038V
OR0000007	ORING, 2-039V
OR0000015	ORING, 2-117V
OR0000016	ORING, 2-120V
OR0000025	ORING, 2-133V

OR0000027	ORING, 2-042V
OR0000039	ORING, 2-012V
OR0000046	ORING, 2-019V
OR0000083	ORING, 105M, 1MM W X 5 MM ID, VITON
OR0000084	ORING, 2-020V
OR0000094	ORING, 2-228V, 50 DURO VITON(KB)
PU0000022	REBUILD KIT, FOR PU20 & 04241 (KB)
RL0000015	RELAY, DPDT, (KB)
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *(KB)
SW0000059	PRESSURE SENSOR, 0-15 PSIA, ALL SEN
WR0000008	POWER CORD, 10A(KB)

Appendix C:

Company: _____ Contact Name: _____

Phone Number: _____ Fax Number: _____ Email: _____

Site Address: _____

Can we connect to the instrument? If so, provide IP address or modem #: _____

Model Serial Number: _____ Firmware revision: _____

The serial number can be found on the back of the instrument, the firmware revision is displayed in the upper left corner of the display when pressing SETUP on the front panel (Example: **C.3**).

1. List all front panel error/warning messages: _____

_____

2. Please complete the following table: (Depending on options installed, not all test parameters shown below may be available in your instrument)

PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE	PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE
RANGE	ppb/ppm	50 ppb - 20 ppm	**SO2 SLOPE**		1.0 ± 0.3
H2S STB	ppb	≤ 1 ppb with zero air	**SO2 OFFS**	mV	< 250
SAMP FL	cm^3/min	600 ± 75	**H2S SLOPE**		
PRES	IN-HG-A	~5"<ambient	**H2S OFFS**	mV	< 250
PMT signal with zero air	mV	-20 to 150	**HVPS**	V	400-900
PMT signal at span gas conc	mV ppb/ppm	0-5000 0-20 000 ppb	**RCELL TEMP**	°C	50 ± 1
NORM PMT at span gas conc	mV ppb/ppm	0-5000 0-20 000 ppb	**BOX TEMP**	°C	Ambient + ~5
UV LAMP	mV	1000 to 4800	**PMT TEMP**	°C	7 ± 2
LAMP RATIO	%	30-120%	**IZS TEMP**	°C	50 ± 3
STR. LGT	ppm	≤ 100 ppb/ zero air	**CONV TEMP**	°C	315 ± 5
DARK PMT	mV	-50 to 200	**ETEST** (DIAG menu)	mV	2000 ± 1000
DARK LAMP	mV	-50 to 200	**OTEST** (DIAG menu)	mV	2000 ± 1000

3. Has the analyzer been checked for leaks? Yes ☐ No ☐ For proper flows? Yes ☐ No ☐

4. What are the failure symptoms? _____

_____

_____ Continue on back if necessary

5. Which tests have you done trying to solve the problem? _____

_____

_____ *Continue on back if necessary*

6. If possible, fax a portion of a strip chart or email a data file to customer service.

CUSTOMER SERVICE CONTACT INFORMATION: 6565 Nancy Ridge Drive, San Diego, CA 92121.
PHONE: +1 858 657 9800 or 1-800 324 5190. FAX: +1 858 657 9816. EMAIL: api-customerservice@teledyne.com.
You can access and submit an online version of this form at http://www.teledyne-api.com/forms/p-fm101e.asp