

# TÜV RHEINLAND IMMISSIONSSCHUTZ UND ENERGIESYSTEME GMBH

Akkreditiertes Prüfinstitut



Translation of the report on the suitability test of the ambient air measuring system M100E of the company Teledyne Advanced Pollution Instrumentation for the measurement of SO<sub>2</sub>

**TÜV-Report: 936/21205926/B1**  
Cologne, 22.06.2007

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**TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of  
DIN EN ISO/IEC 17025**

For the following field of work:

- Determination of emissions and immissions of air pollutants and odorants;
- Verification of the correct installation and the function as well as the calibration of continuous operating emission measuring systems including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and immissions as well as for electronic systems for data evaluation and remote monitoring of emissions

The accreditation is valid up to 04-12-2010. DAR-Registration number: DAP-PL-3856.99.

The publication of extracts is subject to approval by  
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Translation of the report on the suitability test of the ambient air measuring system M100E of the company Teledyne Advanced Pollution Instrumentation for the measurement of SO<sub>2</sub>,  
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Translation of the report on the suitability test of the ambient air measuring system M100E of the company Teledyne Advanced Pollution Instrumentation for the measurement of SO<sub>2</sub>

<b>Tested measuring system:</b>	M100E
<b>Manufacturer of the instrument:</b>	Teledyne Advanced Pollution Instrumentation 9480 Carroll Park Drive San Diego, CA 92121 USA  EAS Envimet Analytical Systems Ges.m.b.h. Industriestrasse B 16 2345 Brunn/Gebirge Austria
<b>Time period of testing:</b>	September 2006 to June 2007
<b>Date of report:</b>	22.06.2007
<b>Number of report:</b>	936/21205926/B1
<b>Scope of report:</b>	In total 428 pages Manual from page 74 with 354 pages

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## 1. Summary and proposal for declaration of suitability

### 1.1 Summary

On behalf of Teledyne Advanced Pollution Instrumentation TÜV Rheinland Immissionsschutz und Energiesysteme GmbH has performed the suitability test of the measuring system M100E for the components SO<sub>2</sub>.

The suitability test was carried out in compliance with the following guidelines and requirements:

- VDI 4202 Part 1: Minimum requirements for suitability tests of automated air quality measuring systems – point related measurement methods of gaseous and particulate pollutants, June 2002
- VDI 4203 Part 3: Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants, August 2004
- EN 14212 Ambient air quality – Standard method for the measurement of the concentration of sulfur dioxide by ultraviolet fluorescence, June 2005

The measuring system M100E operates using the ultraviolet fluorescence method.

The investigations have been carried out in the laboratory and during a field test, lasting three months.  
The tested measuring ranges are:

Component		Measuring range		
Sulfur dioxide	SO <sub>2</sub>	700	µg/m <sup>3</sup>	VDI 4202 Bl. 1
Sulfur dioxide	SO <sub>2</sub>	1000	µg/m <sup>3</sup>	EN 14212

NOTE: 0 – 0,376 ppm are conform to 0 – 376 nmol/mol or 0 – 1000 µg/m<sup>3</sup> (at 293 K and 1013mbar)

The minimum requirements have been fulfilled in the suitability test.

Therefore the TÜV Rheinland Immissionsschutz und Energiesysteme GmbH proposes the publication as a suitability-tested measuring system for continuous monitoring of SO<sub>2</sub> in the ambient air.

## 1.2 Proposal for declaration of suitability

Due to the positive achieved results, the following recommendation for declaration of suitability as suitability-tested measuring system is given:

- 1.2.1 Measurement task** : Measuring system for determination of the SO<sub>2</sub> concentration in the ambient air
- 1.2.2 Name of device** : M100E
- 1.2.3 Measured components** : SO<sub>2</sub>
- 1.2.4 Manufacturer** : Teledyne Advanced Pollution Instrumentation  
9480 Carroll Park Drive  
San Diego, CA 92121  
USA
- EAS Envimet Analytical Systems Ges.m.b.h.  
Industriestrasse B 16  
2345 Brunn/Gebirge  
Austria
- 1.2.5 Suitability** : For continuous ambient air measurement of SO<sub>2</sub>
- 1.2.6 Measuring ranges in the suitability test** : Sulfur dioxide 0 - 700 µg/m<sup>3</sup>  
Sulfur dioxide 0 - 1000 µg/m<sup>3</sup>
- 1.2.7 Software version** : Revision C.3
- 1.2.8 Restrictions** : -
- 1.2.9 Remarks** : -
- 1.2.10 Test house** : TÜV Rheinland Immissionsschutz und Energiesysteme GmbH,  
Köln  
TÜV Rheinland Group  
Responsible investigator: Dipl.-Ing. Martin Schneider
- 1.2.11 Test report** : 936/21205926/B1 from 22.06.2007

## 2. Terms of reference

### 2.1 Kind of testing

On behalf of the company Teledyne API, TÜV Rheinland Immissionsschutz und Energiesysteme GmbH performed a complete suitability test for the measuring system M100E. The test was performed as a complete suitability test regarding the minimum requirements.

### 2.2 Objektive

The objective of the test was to show, that the measuring system fulfils the German minimum requirements and the requirements of the EN 14212. Therefore the measuring system was tested in the following measuring ranges:

Table 1: *Tested measuring ranges*

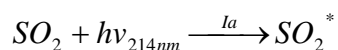
Component		Measuring range		
Sulfur dioxide	SO <sub>2</sub>	700	µg/m <sup>3</sup>	VDI 4202 Bl. 1
Sulfur dioxide	SO <sub>2</sub>	1000	µg/m <sup>3</sup>	EN 14212

### 3. Description of the measured system

#### 3.1 Measuring principle

The physical principle upon which the M100E's measurement method is based is the fluorescence that occurs when sulfur dioxide (SO<sub>2</sub>) is excited by ultraviolet light with wavelength in the range of 190 nm – 230 nm. This reaction is a two-step process.

The first stage occurs when SO<sub>2</sub> molecules are struck by photons of the appropriate ultraviolet wavelength. In the case of the model 100E, a band pass filter between the source of the UV light and the affected gas limits the wavelength of the light to approximately 214 nm. The SO<sub>2</sub> molecules absorb some of the energy from the UV light causing one of electrons of each of the affected molecules to move to a higher energy orbital state.



The amount SO<sub>2</sub> converted to excited SO<sub>2</sub><sup>\*</sup> in the sample chamber is dependent on the average intensity of the UV light and not its peak intensity because the intensity of UV light is not constant in every part of sample chamber. Some of the photons are absorbed by the SO<sub>2</sub> as the light travels through the sample gas.

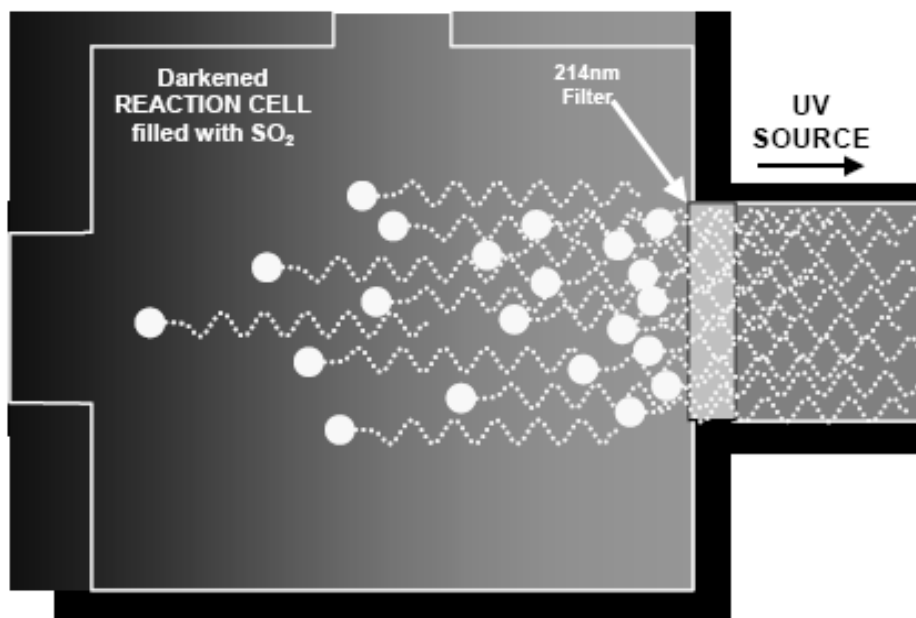


Figure 1: UV Absorption



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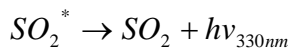
The equation for defining the average intensity of the UV light ( $I_a$ ) is:

$$I_a = I_0 [1 - \exp(-ax(SO_2))]$$

Where:

- $I_0$  = Intensity of the excitation UV light.
- $A$  = The absorption coefficient of SO<sub>2</sub> (a constant).
- SO<sub>2</sub> = Concentration of SO<sub>2</sub> in the sample chamber.
- $X$  = The distance between the UV source and the SO<sub>2</sub> molecules being affected (path length)

The second stage of this reaction occurs after the SO<sub>2</sub> reaches its excited state (SO<sub>2</sub><sup>\*</sup>). Because the system will seek the lowest available stable energy state, the SO<sub>2</sub><sup>\*</sup> molecule quickly returns to its ground state by giving off the excess energy in the form of a photon (hv). The wavelength of this fluoresced light is also in the ultraviolet band but at a longer (lower energy) wavelengths centered at 330nm.



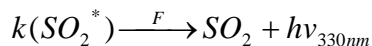
The amount of detectable UV given off by the decay of the SO<sub>2</sub><sup>\*</sup> is affected the rate at which this reactions occurs (k).

$$F = k(SO_2^*)$$

Where:

- $F$  = the amount of fluorescent light given off.
- $K$  = The rate at which the SO<sub>2</sub><sup>\*</sup> decays into SO<sub>2</sub>
- SO<sub>2</sub><sup>\*</sup> = Amount of excited SO<sub>2</sub> in the sample chamber

SO:



Finally, the function (k) is affected by the temperature of the gas. The warmer the gas, the faster the individual molecules decay back into their ground state and the more photons of UV light are given off per unit of time.

In summary, given that the absorption rate of SO<sub>2</sub> (a) is constant, the amount of fluorescence (F) is a result of the SO<sub>2</sub> concentration, the intensity of UV light, the path length of the UV light and the temperature of the gas.

So, when and the intensity of the light is known, path length of excited light is short, the temperature is known and compensated for so that the rate of SO<sub>2</sub><sup>\*</sup> decay is constant. And no interfering conditions are present, the amount of fluorescent light emitted is directly related to the concentration of the SO<sub>2</sub> in the sample chamber.

### 3.2 Components of the analyzer

#### Sample gas flow:

The flow of gas through the M100E UV Fluorescence SO<sub>2</sub> analyzer is created by a small internal pump that pulls air through the instrument.

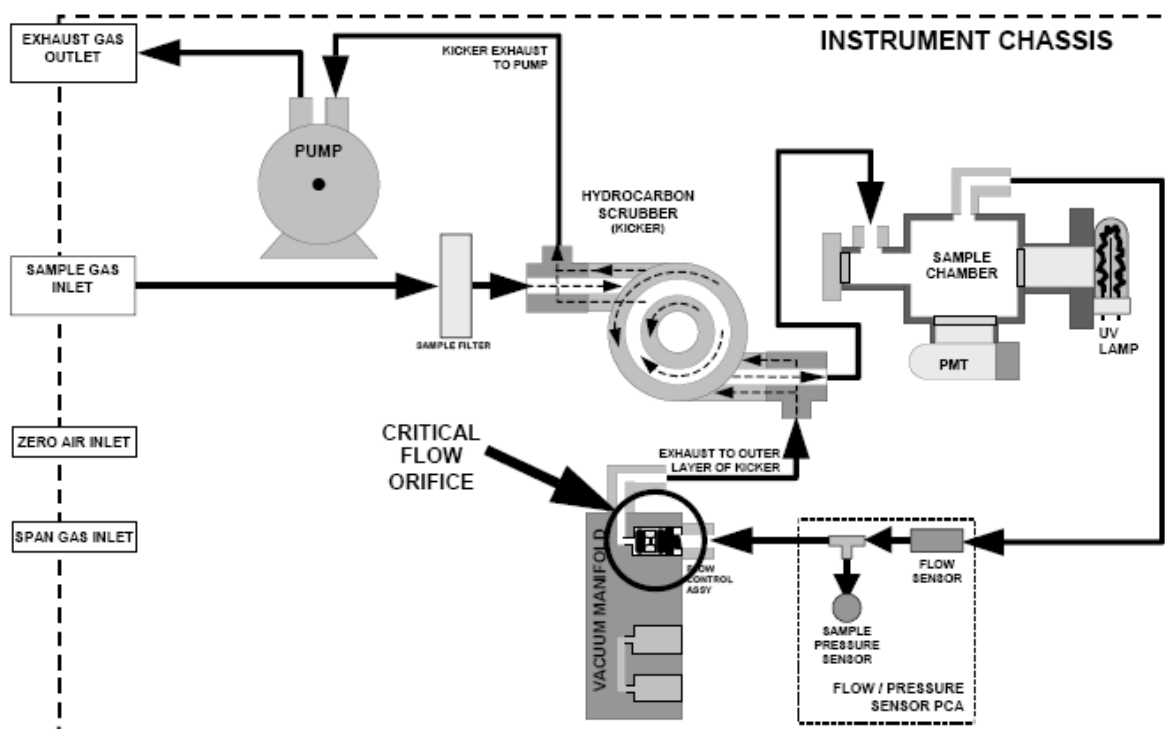


Figure 2: M100E Gas flow

#### The PMT

The amount of fluoresced UV produced in the sample chamber is much less than the intensity of excitation UV source lamp (Therefore a much more sensitive device is needed to detect this light with enough resolution to be meaningful. The Model 100E uses a Photo Multiplier Tube or PMT for this purpose.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by a high voltage applied across a series of special electrodes called dynodes that multiply the amount of electrons until a useable current signal is generated. This current increases or decreases with the amount of detected light (see Section 10.4.3 for more details regarding the electronic operation of the PMT).

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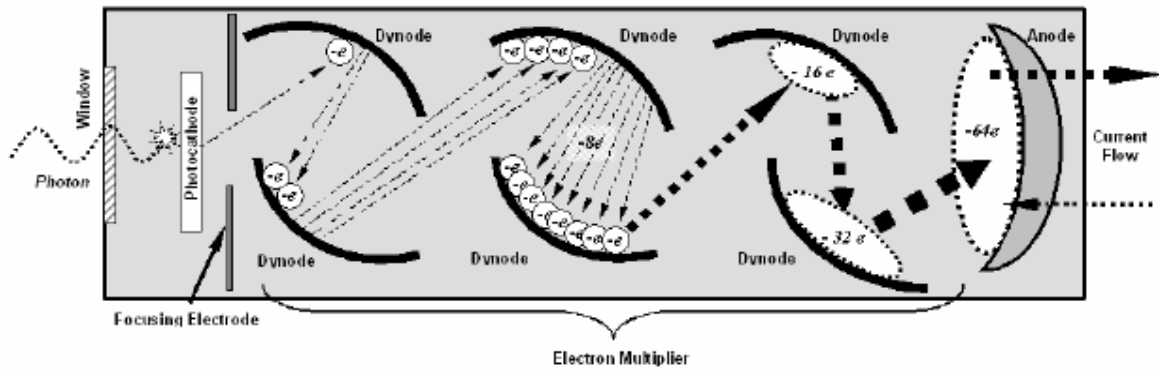


Figure 3: Basic PMT design

UV light path:

UV radiation is generated by a lamp specifically designed to produce a maximum amount of light of the wavelength needed to excite SO<sub>2</sub> in SO<sub>2</sub><sup>+</sup> (214nm) and a special reference detector circuit constantly measures lamp intensity. A photo Multiplier Tube (PMT) detects the UV given off by SO<sub>2</sub><sup>+</sup> decay (330 nm) and outputs an analog signal. Several focusing lenses and optical filters make sure that both detectors are exposed to an optimum amount of only the right wavelengths of UV. To further assure that the PMT only detects light given off by decaying SO<sub>2</sub><sup>+</sup> the pathway of the excitation UV and field of view of the PMT are perpendicular to each other and the inside surfaces of the sample chamber are coated with a layer of black Teflon that absorbs stray light.

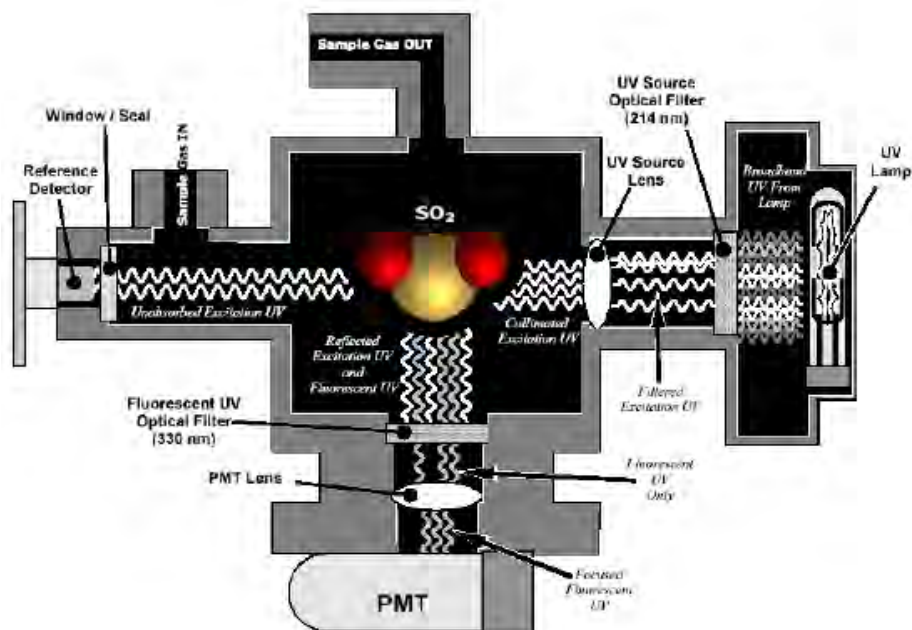


Figure 4: UV Light path

### Hydrocarbon Scrubber (kicker)

It is very important to make sure the air supplied sample chamber is clear of hydrocarbons. To accomplish this task the M100E uses a single tube permeation scrubber. The scrubber consists of a single tube of a specialized plastic that absorbs hydrocarbons very well. This tube is located within outer flexible plastic tube shell. As gas flows through the inner tube, hydrocarbons are absorbed into the membrane walls and transported through the membrane wall and into the hydrocarbon free, purge gas flowing through the outer tube. This process is driven by the hydrocarbon concentration gradient between the inner and outer of the tubes.

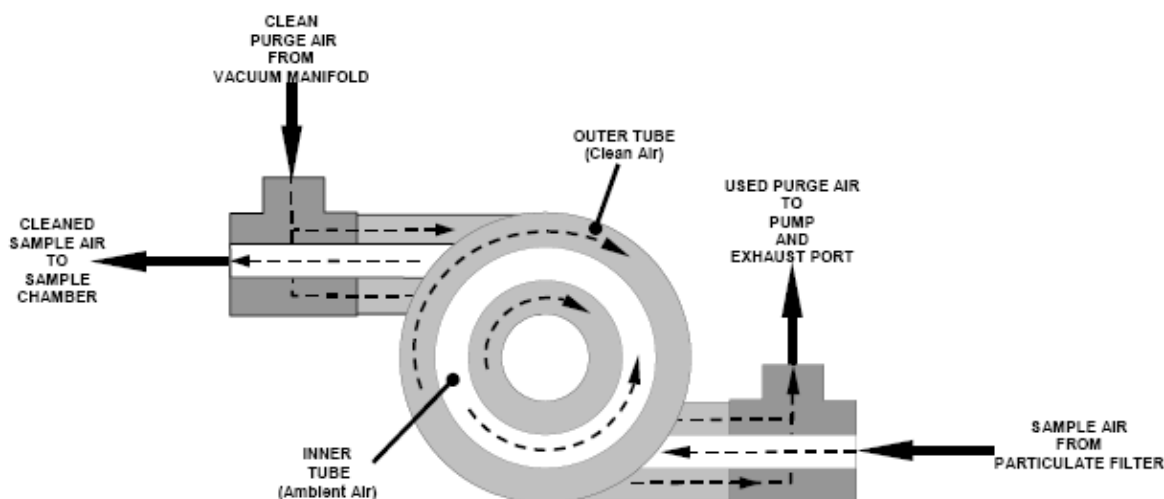


Figure 5: M100E Hydrocarbon Scrubber (kicker)

In the M100E some of the cleaned air from the inner tube is returned to used as the purge gas in the outer tube. This means that when the analyzer is first started, the concentration gradient between the inner and outer tubes is not very large and the scrubber's efficiency is relatively low. When the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the gradient to become large enough for the scrubber to adequately remove hydrocarbons from the sample air.

### The reference detector

A vacuum diode, UV detector that converts UV light to a DC current is used to measure the intensity of the excitation UV source lamp. Its location, directly across from the source lamp at the back of a narrow tube-shaped light trap, places it directly in the path of the excitation UV light. A window transparent to UV light provides an air-proof seal that prevents ambient gas from contaminating the sample chamber. The shape of the light trap and the fact that the detector is blind to wavelengths other than UV no extra optical filtering is needed.

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#### 4. Test programm

The lab and the field test has been carried out with two identical sulfur dioxide analyzers of the type M100E with the following serial numbers

Device 1: No. 1177

Device 2: No. 1183

The field test took place from the 13.02.2007 to the 14.05.2007 The analyzers have been installed during the field test in an air conditioned container. During the tests the analyzers were configured with the following electronic measuring ranges.

Component		Measurement range	
Sulfur dioxide	SO <sub>2</sub>	0 - 400	ppb

The evaluation based on the in table 1 mentioned certification ranges.



Figure 6: Picture of the analyzers in the measuring container

#### **4.1 Test program according VDI 4202, see results in chapter 6**

According to the requirements of the guideline VDI 4202 part 1 the following laboratory test program was established:

- Inspection of the general analyzer functions
- Determination of the device characteristic with test gases,
- Determination of the cross sensitivities against accompanying substances in the ambient air
- Test of the stability of the zero and span point in the allowed ambient temperature range,
- Determination of the influence of changes in the mains voltage to the measuring signal,
- Determination of the detection limit,
- Determination of the response time,
- Determination of the total uncertainty,
- Determination of the converter efficiency

According to the requirements of the guideline VDI 4202 part 1 the following field test program was established:

- Inspection of the general analyzer functions
- Functional check of the analyzer at the beginning and at the end of the field test,
- Determination of the detection limit,
- Determination of the maintenance interval,
- Reproducibility standard deviation,
- Long term drift at zero and span,
- Period of unattended operation,
- Availability of the analyzer,
- Determination of the total uncertainty.

#### **4.2 Test program according EN 14212, see results in chapter 7**

According to the requirements of the guideline DIN EN 14212 the following laboratory test program was established:

- Inspection of the general analyzer functions
- Determination of the repeatability at zero and span
- Lack of fit
- Sensitivity coefficient of sample gas pressure
- Sensitivity coefficient of sample gas temperature
- Sensitivity coefficient of surrounding temperature
- Sensitivity coefficient of electrical voltage
- Interferents at zero and span
- Averaging effect
- Short term drift at zero and span
- Response time
- Converter efficiency
- Difference between sample/calibration port
- Determination of the total uncertainty

According to the requirements of the guideline DIN EN 14212 the following field test program was established:

- Functional check of the analyzer at the beginning and at the end of the field test,
- Determination of the maintenance interval,
- Reproducibility standard deviation,
- Long term drift at zero and span,
- Period of unattended operation,
- Availability of the analyzer,
- Determination of the total uncertainty.

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## 5. Reference method

### 5.1 SO<sub>2</sub> test gas

The SO<sub>2</sub> test gas has been produced by means of a permeation oven of the company MCZ during the tests in the laboratory and the field. For the validation of the produced SO<sub>2</sub> concentration and for the determination of the permeation rate of the used permeation tube the weight difference of the tube is checked weekly. During this time the permeation tube was stored under defined climatic circumstances

These gravimetric determination of the permeation rate has been done continuously during the complete suitability test. From the regular gravimetric checks there is an uncertainty of  $\pm 1\%$  of the test gas resulting.

In addition different measurements with the TCM-method after VDI 2451 part 3 have been done at different concentration levels. Each adjusted concentration of the permeation system has been compared with the measured concentration of the analyzers and the TCM-method.

### 5.2 Assembly in the lab and field

The set-up of the testing arrangement in the laboratory was matched to the requirements of the specific tests and was duplicated in a simplified manner in the field test site (see Figure 7).



Figure 7: Test gas application by permeation system and computer for controlling

## **6. Typ approval regarding VDI 4202 BI.1**

This chapter contains the test results regarding the German guideline VDI 4202 BI. 1. The test results fulfill the criteria's of the guideline. The evaluation is only of interest for the approval in Germany. Therefore a translation of this chapter has been omitted. The test results can be seen in the German version of this test report.



## 7 Test requirements according EN 14212

### 7.1 8.4 Determination of the performance characteristics during the laboratory test

A designated body shall perform the determination of the performance characteristics in the laboratory as apart of the type approval test. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this document. The test shall be performed on at least 2 analyzers in the laboratory test.

#### 8.4.2 Test conditions

##### 8.4.2.1 General

Before operating the analyzer, the operating instructions of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable products necessary.

The analyzer should be allowed to warm up during the time specified by the manufacturer before undertaking any tests. If the warm-up time is not specified, a minimum of 4 hours is recommended.

When applying test gases to the analyzer, the test gas system shall be operated sufficiently long before starting the tests in order to stabilize the concentrations applied to the analyzer.

Most analyzer systems are able to give an output signal as a moving average over an adjustable period of time and some systems automatically change this integration time as a function of the frequency of the fluctuations in concentration of the detected pollutant. These options are typically used in order to smooth output data. It needs to be demonstrated that the set value for the averaging time or the use of an active filter will not influence the result of the averaging test and response time set.

During laboratory and field tests for the type approval the settings of the monitor shall be as the manufacturer requires. All settings shall be noted down in the test report.

##### 8.4.2.2 Parameters

For the determination of the various performance characteristics, test traceable to national standards shall be used, unless otherwise stated in this document.

##### 8.4.2.3 Test gases

For the determination of the various performance characteristics, test gases ((synthetic) air containing a certain concentration) traceable to national standards shall be used, unless otherwise stated in this document. The uncertainties in zero and span gases used for the laboratory and field tests shall be proven to be insignificant.

### 7.2 Evaluation

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH holds an accreditation under the terms of DIN EN ISO/IEC 17025.

The Laboratory test has been performed regarding the required quality standard of EN 14212 with two analyzers of type M100E.

**Table 2: Relevant performance characteristics and criteria according to EN 14212**

No.	Performance characteristic	Symbol	Clause	Performance criterion
1	Repeatability standard deviation at zero	$S_{r,z}$	8.4.5	$\leq 1,0 \text{ nmol/mol}$
2	Repeatability standard deviation at concentration $c_t$ (at a level of the hourly limit value)	$S_{r,ct}$	8.4.5	$\leq 3,0 \text{ nmol/mol}$
3	"Lack of fit" (residual from the linear regression function)		8.4.6	
3a	Largest residual from the linear regression function at concentrations higher than zero	$X_i$		$\leq 4 \%$ of the measured value
3b	Residual at zero	$X_{i,z}$		$\leq 5,0 \text{ nmol/mol}$
4	Sensitivity coefficient of sample gas pressure	$b_{gp}$	8.4.7	$\leq 3,0 \text{ nmol/mol/kPa}$
5	Sensitivity coefficient of sample gas temperature	$b_{gt}$	8.4.8	$\leq 1,0 \text{ nmol/mol/K}$
6	Sensitivity coefficient of surrounding temperature	$b_{st}$	8.4.9	$\leq 1,0 \text{ nmol/mol/K}$
7	Sensitivity coefficient of electrical voltage	$b_v$	8.4.10	$\leq 0,3 \text{ nmol/mol/V}$
8	Interference at zero at concentration $c_t$ (at a level of the 8-hour mean limit value)		8.4.11	
8a	H <sub>2</sub> O with concentration 19mmol/mol	$X_{H_2O,z.ct}$		H <sub>2</sub> O $\leq 10 \text{ nmol/mol}$
8b	H <sub>2</sub> S with concentration 200 $\mu\text{mol/mol}$	$X_{H_2S,z.ct}$		H <sub>2</sub> S $\leq 5,0 \text{ nmol/mol}$
8c	NH <sub>3</sub> with concentration 200 nmol/mol	$X_{NH_3,z.ct}$		NH <sub>3</sub> $\leq 5,0 \text{ nmol/mol}$
8d	NO with concentration 500 nmol/mol	$X_{NO,z.ct}$		NO $\leq 5,0 \text{ nmol/mol}$
8e	NO <sub>2</sub> with concentration 200 nmol/mol	$X_{NO_2,z.ct}$		NO <sub>2</sub> $\leq 5,0 \text{ nmol/mol}$
8f	m-Xylol with concentration 1 $\mu\text{mol/mol}$	$X_{m-xyl,z.ct}$		m-xylol $\leq 10,0 \text{ nmol/mol}$
9	Average effect	$X_{av}$	8.4.12	$\leq 7,0 \%$ of the measured value
10	Reproducibility standard deviation under field conditions	$S_{r,f}$	8.5.5	$\leq 5,0 \%$ of the average of a three month period
11	Long-term drift at zero	$D_{l,z}$	8.5.4	$\leq 5,0 \text{ nmol/mol}$
12	Long-term drift at span level	$D_{l,s}$	8.5.4	$\leq 5,0 \%$ of maximum of certification range
13	Short-term drift at zero	$D_{s,z}$	8.4.4	$\leq 2,0 \text{ nmol/mol}$ over 12 h
14	Short-term drift at span	$D_{s,s}$	8.4.4	$\leq 6,0 \text{ nmol/mol}$ over 12 h
15	Response time (rise)	$t_r$	8.4.3	$\leq 180 \text{ s}$
16	Response time (fall)	$t_f$	8.4.3	$\leq 180 \text{ s}$
17	Difference between rise and fall time	$t_d$	8.4.3	$\leq 10 \%$ relative difference, or 10 s, whatever is greater
18	Difference between sample/calibration port	$D_{sc}$	8.4.13	$\leq 1 \%$
19	Period of unattended operation		8.5.6	3 month or longer
20	Availability of the analyzer	$A_a$	8.5.7	$> 90 \%$

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### **7.3 Findings**

A summary of the evaluation is mentioned at Table 30 on page 68 and 69.

Minimum requirement fulfilled? yes

### **7.4 Presentation of results**

Here not necessary.

## 7.1 8.4.3 Response time

*Response time (rise) and Response time (fall) ≤ 180 s. The difference between rise- and fall time ≤ 10 % relative difference, or 10 s, whatever is the greatest.*

## 7.2 General requirements

The response time of the analyzer shall be determined at the nominal sample flow rate specified by the manufacturer.

The sample flow rate shall be kept constant within the requirements as given in 8.4.2 (± 1 %) during the test.

The determination of the response time shall be carried out by applying to the analyzer a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range and vice versa (see Figure 8).

The change from zero gas to span gas needs to be made almost instantly with the use of a suitable valve. The valve outlet shall be mounted direct to the inlet of the analyzer, and both zero gas and span gas shall have the same "oversupply" which is vented with the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyzer system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start (t = 0) of the (rise) lag time according to Figure 8. When the reading of 98 % of the applied concentration has been reached, the span gas can be changed to zero again, and this event is the start (t = 0) of the (fall) lag time. When the reading of 2 % of the applied concentration has been reached the whole cycle as shown in Figure 8 is complete.

The time between the beginning and the achievement of 90 % of the stable display has been determined. The total cycle must be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) have been calculated.

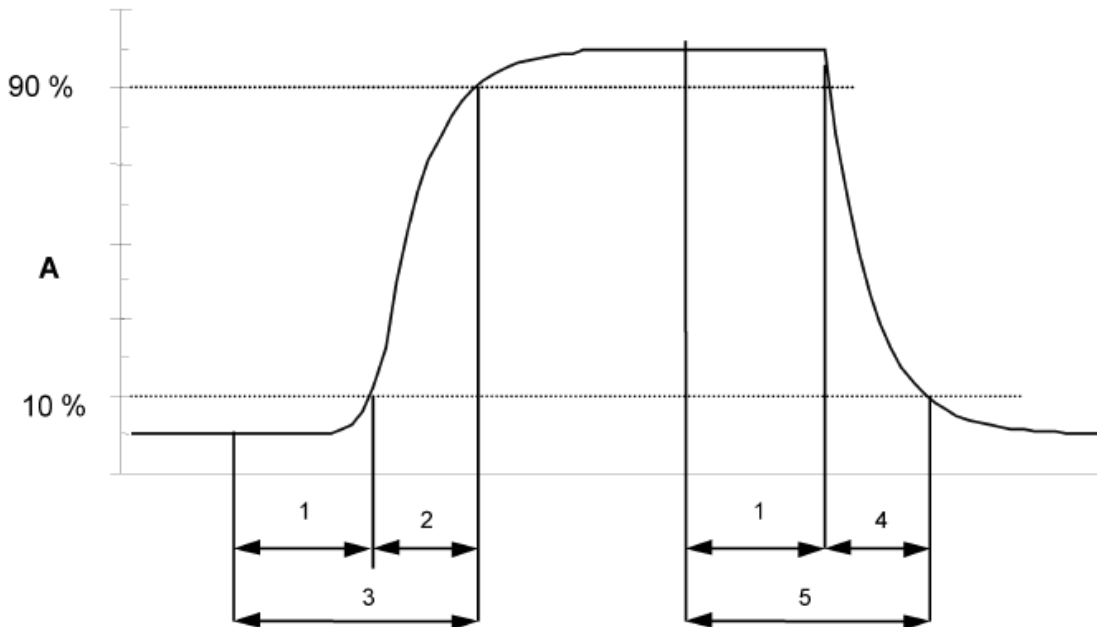
The relative difference in response times shall be calculated according to:

$$t_d = \left| \frac{t_r - t_f}{t_r} \right| \times 100\%$$

Where  $t_d$  is the relative difference between response time (rise) and response time (fall) (%)  
 $t_r$  is the average response time (rise) (average of 4 measurements) (s)  
 $t_f$  is the average response time (fall) (average of 4 measurements) (s)

$t_r$ ,  $t_f$  and  $t_d$  shall comply with the performance criterion.

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#### Key

- A Analyser response
- 1 Lag time
- 2 Rise time
- 3 Response time (rise)
- 4 Fall time
- 5 Response time (fall)

Figure 8: Diagram illustrating the response time

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212. The data recording has been done with a data logger VDM Memograph of Endress und Hauser with a averaging time of 1s.

The response time has to be determined according to the EN 14212 for the component SO<sub>2</sub>.

## 7.4 Evaluation

Table 3: Response times of the two analyzers

Start Value [ppb]	Target Value 90 % [ppb]		Time Device 1177 [s]	Time Device 1183 [s]	Requirement DIN EN 14212 [s]	Requirement fulfilled?
0	270	$t_r$	77	74	180	yes
300	30	$t_f$	75	78	180	yes
<b>Difference</b>			<b>2</b>	<b>4</b>		
0	270	$t_r$	76	80	180	yes
300	30	$t_f$	79	76	180	yes
<b>Difference</b>			<b>3</b>	<b>4</b>		
0	270	$t_r$	74	75	180	yes
300	30	$t_f$	77	80	180	yes
<b>Difference</b>			<b>3</b>	<b>5</b>		
0	270	$t_r$	78	77	180	yes
300	30	$t_f$	80	79	180	yes
<b>Difference</b>			<b>2</b>	<b>2</b>		

For device 1 (1177) a maximum  $t_r$  of 78 s, a maximum  $t_f$  of 80 s and a  $t_d$  of 2,0 % has been calculated.  
For device 2 (1183) a maximum  $t_r$  of 80 s, a maximum  $t_f$  of 80 s and a  $t_d$  of 2,3 % has been calculated.

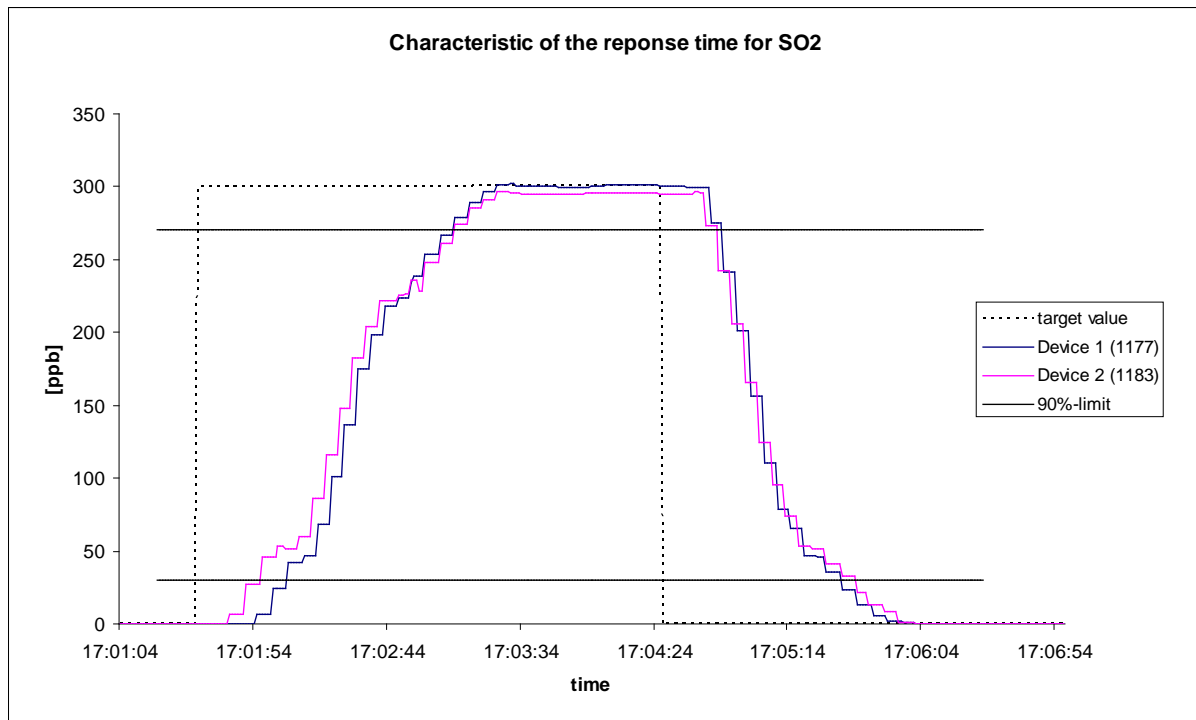


Figure 9: Characteristics of the response time

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## **7.5 Assessment**

The determined response time is clearly below the allowed response time of 180 s. The relative difference between rise time and fall time fulfills the requirement of EN 14212.

Minimum requirement fulfilled? yes

## **7.6 Presentation of test results**

Here not necessary.

## 7.1 8.4.4 Short-term drift

*Short-term drift at zero  $\leq 2,0$  nmol/mol/12h (equal to 2 ppb/12h)*

*Short-term drift at span  $\leq 6,0$  nmol/mol/12h (equal to 6 ppb/12h)*

## 7.2 General requirements

After the required stabilization period, the analyzer shall be adjusted at zero and span level (around 70 % to 80 % of the maximum of the certification range). Wait the time equivalent to one independent reading and then record 20 individual measurements first at zero and then at span concentration. From these 20 measurements the average is calculated for zero and span level.

The analyzer shall be kept running under the laboratory conditions whilst analyzing ambient air. After a period of 12-hours zero and span gas is fed to the analyzer. Wait the time equivalent to one independent reading and then record 20 individual measurements first at zero and then at span concentration. The averages for zero and span level shall be calculated.

The short-term drift at zero and span level shall be calculated as follows:

$$D_{S,Z} = (C_{Z,2} - C_{Z,1})$$

Where:

$D_{S,Z}$  is the 12-hour drift at zero (nmol/mol);

$C_{Z,1}$  is the average of the zero gas measurements at the beginning of the drift period (just after calibration) (nmol/mol);

$C_{Z,2}$  is the average of the zero gas measurements at the end of the drift period (12h) (nmol/mol).

$D_{S,Z}$  shall comply with the performance criterion.

$$D_{S,S} = (C_{S,2} - C_{S,1}) - D_{S,Z}$$

Where:

$D_{S,S}$  is the 12-hour drift at span (nmol/mol);

$C_{S,1}$  is the average of the span gas measurements at the beginning of the drift period (just after calibration) (12h) (nmol/mol);

$C_{S,2}$  is the average of the span gas measurements at the end of the drift period (12h) (nmol/mol).

$D_{S,S}$  shall comply with the performance criterion.



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### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212.

### 7.4 Evaluation

Table 4: Results of the short-term drift

	Device 1 (1177)	Device 2 (1183)
	[ppb]	[ppb]
$C_{z,1}$	0,5	0,0
$C_{z,2}$	0,5	0,4
$D_{s,z}$	<b>0,0</b>	<b>0,4</b>
Requirement fulfilled ?	2 ppb <b>yes</b>	2 ppb <b>yes</b>
$C_{s,1}$	261,1	262,1
$C_{s,2}$	259,7	261,1
$D_{s,s}$	<b>-1,4</b>	<b>-1,4</b>
Requirement fulfilled ?	6 ppb <b>yes</b>	6 ppb <b>yes</b>

### 7.5 Assessment

The following short-term drift at zero ( $D_{s,z}$ ) has been determined:

Device 1 (1177): 0,0 ppb/12 h

Device 2 (1183): 0,4 ppb/12 h

The following short-term drift at span ( $D_{s,s}$ ) has been determined:

Device 1 (1177): -1,4 ppb/12 h

Device 2 (1183): -1,4 ppb/12 h

The short-term drift requirements of EN 14212 have been fulfilled.

Minimum requirement fulfilled? yes

### 7.6 Documentation

The measured values are stated in Table 5 and Table 6.

**Table 5: Measured values of short-term drift regarding EN 14212, device 1 (1177)**

Initial Value (18.01.2007)				Nr.	Value after 12 h (18.01.2007)			
Zero Point		Span Point			Zero Point		Span Point	
[Time]	[ppb]	[Time]	[ppb]		[Time]	[ppb]	[Time]	[ppb]
07:25	0,4	8:13	260,8	1	19:30	0,8	20:18	262,0
07:27	0,0	8:15	260,8	2	19:32	0,4	20:20	261,6
07:29	0,4	8:17	260,8	3	19:34	0,4	20:22	261,6
07:31	0,4	8:19	260,4	4	19:36	0,8	20:24	261,2
07:33	0,4	8:21	262,0	5	19:38	0,4	20:26	261,6
07:35	0,4	8:23	262,0	6	19:40	0,4	20:28	262,8
07:37	0,8	8:25	262,8	7	19:42	0,4	20:30	263,2
07:39	0,8	8:27	262,4	8	19:44	0,8	20:32	262,0
07:41	0,4	8:29	260,8	9	19:46	0,8	20:34	262,8
07:43	0,8	8:31	260,0	10	19:48	0,8	20:36	262,0
07:45	0,8	8:33	261,2	11	19:50	0,4	20:38	261,6
07:47	0,8	8:35	262,0	12	19:52	0,4	20:40	261,2
07:49	0,8	8:37	261,6	13	19:54	0,4	20:42	261,2
07:51	0,4	8:39	260,8	14	19:56	0,0	20:44	261,2
07:53	0,4	8:41	261,2	15	19:58	0,0	20:46	220,8
07:55	0,4	8:43	260,8	16	20:00	0,4	20:48	260,8
07:57	0,4	8:45	260,8	17	20:02	0,4	20:50	261,6
07:59	0,4	8:47	260,4	18	20:04	0,8	20:52	262,0
08:01	0,4	8:49	260,8	19	20:06	0,4	20:54	260,8
08:03	0,8	8:51	260,0	20	20:08	0,8	20:56	261,2
<b>Average</b>	<b>0,5</b>	<b>Average</b>	<b>261,1</b>		<b>Average</b>	<b>0,5</b>	<b>Average</b>	<b>259,7</b>

**Table 6: Measured values of short-term drift regarding EN 14212, device 2 (1183)**

Initial Value (18.01.2007)				Nr.	Value after 12 h (18.01.2007)			
Zero Point		Span Point			Zero Point		Span Point	
[Time]	[ppb]	[Time]	[ppb]		[Time]	[ppb]	[Time]	[ppb]
07:25	0,4	8:13	262,0	1	19:30	0,4	20:18	261,2
07:27	0,0	8:15	261,2	2	19:32	0,4	20:20	262,0
07:29	0,0	8:17	262,8	3	19:34	0,4	20:22	261,6
07:31	0,0	8:19	262,8	4	19:36	0,4	20:24	260,8
07:33	0,0	8:21	262,4	5	19:38	0,0	20:26	261,2
07:35	0,4	8:23	262,8	6	19:40	0,8	20:28	260,8
07:37	0,0	8:25	262,8	7	19:42	0,4	20:30	261,2
07:39	0,4	8:27	262,8	8	19:44	0,4	20:32	260,4
07:41	0,0	8:29	262,0	9	19:46	0,4	20:34	262,0
07:43	0,4	8:31	262,0	10	19:48	0,4	20:36	260,0
07:45	0,0	8:33	262,0	11	19:50	0,8	20:38	262,8
07:47	0,0	8:35	261,6	12	19:52	0,8	20:40	262,0
07:49	0,0	8:37	261,6	13	19:54	0,4	20:42	260,4
07:51	0,0	8:39	261,2	14	19:56	0,4	20:44	260,4
07:53	0,0	8:41	261,6	15	19:58	0,4	20:46	260,8
07:55	0,0	8:43	261,2	16	20:00	0,4	20:48	260,4
07:57	-0,4	8:45	263,2	17	20:02	0,0	20:50	260,8
07:59	0,0	8:47	262,0	18	20:04	0,4	20:52	260,8
08:01	-0,4	8:49	262,8	19	20:06	0,4	20:54	260,8
08:03	-0,4	8:51	262,0	20	20:08	0,4	20:56	261,6
<b>Average</b>	<b>0,0</b>	<b>Average</b>	<b>262,1</b>		<b>Average</b>	<b>0,4</b>	<b>Average</b>	<b>261,1</b>

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## 7.1 8.4.5 Repeatability standard deviation

*Repeatability standard deviation at zero ≤ 1,0 nmol/mol (equal to 1,0 ppb)*

*Repeatability standard deviation at span ≤ 3,0 nmol/mol (equal to 3,0 ppb)*

## 7.2 General requirements

After waiting the time equivalent of one independent reading 20 individual measurements both at zero concentration and at a test concentration ( $c_t$ ) similar to the hourly limit value shall be performed. From these measurements the repeatability standard deviation ( $s_r$ ) at zero concentration and at concentration  $c_t$  shall be calculated according to:

$$s_r = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

Where:

$s_r$  is the repeatability standard deviation (nmol/mol);

$x_i$  is the  $i$ 'th measurement (nmol/mol);

$\bar{x}$  is the average of the 20 measurements (nmol/mol);

$n$  is the number of measurements,  $n = 20$ .

The repeatability standard deviation shall be calculated separately for both series of measurements (zero gas and concentration  $c_t$ ).

$s_r$  shall comply with the performance criterion, both at zero and at the test concentration  $c_t$  (hourly limit value).

## 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212.

## 7.4 Evaluation

A summary of the determined test results according to EN 14212 is stated in Table 7.

Table 7: Repeatability standard deviation

Measurement		Device 1 (1177)		Device 2 (1183)	
		ZP	SP	ZP	SP
		ppb	ppb	ppb	ppb
Number	n	20	20	20	20
Average	x	0,1	128,8	0,5	130,1
<b>Standard deviation</b>	<b>sr</b>	<b>0,3</b>	<b>0,5</b>	<b>0,3</b>	<b>0,9</b>
<b>Requirement of DIN EN 14212</b>	<b>ppb</b>	<b>1</b>	<b>3</b>	<b>1</b>	<b>3</b>
<b>Requirement fulfilled?</b>		<b>yes</b>	<b>yes</b>	<b>yes</b>	<b>yes</b>

## 7.5 Assessment

Both M100E analyzers fulfill the minimum requirements at zero and span point.

Minimum requirements fulfilled? yes

## 7.6 Presentation of test results

The single measured values of the test are stated in Table 8.

Table 8: Measured values of repeatability standard deviation regarding EN 14212

Date	Time	Zero Point		Date	Time	Span Point	
		Device 1 (1177)	Device 2 (1183)			Device 1 (1177)	Device 2 (1183)
		[ppb]	[ppb]			[ppb]	[ppb]
29.09.2006	08:05 - 08:15	0,4	0,0	29.09.2006	08:15 - 08:25	129,2	130,4
29.09.2006	08:25 - 08:35	0,4	0,0	29.09.2006	08:35 - 08:45	128,4	126,8
29.09.2006	08:45 - 08:55	0,4	0,0	29.09.2006	08:55 - 09:05	129,2	130,4
29.09.2006	09:05 - 09:15	0,4	0,4	29.09.2006	09:15 - 09:25	129,2	131,2
29.09.2006	09:25 - 09:35	0,4	0,4	29.09.2006	09:35 - 09:45	128,0	130,4
29.09.2006	09:45 - 09:55	0,4	0,4	29.09.2006	09:55 - 10:05	128,8	130,0
29.09.2006	10:05 - 10:15	0,4	0,4	29.09.2006	10:15 - 10:25	129,2	130,8
29.09.2006	10:25 - 10:35	0,0	0,4	29.09.2006	10:35 - 10:45	129,2	130,0
29.09.2006	10:45 - 10:55	0,0	0,4	29.09.2006	10:55 - 11:05	128,8	130,0
29.09.2006	11:05 - 11:15	0,0	0,4	29.09.2006	11:15 - 11:25	128,4	130,4
29.09.2006	11:25 - 11:35	0,0	0,4	29.09.2006	11:35 - 11:45	129,2	130,0
29.09.2006	11:45 - 11:55	0,0	0,4	29.09.2006	11:55 - 12:05	128,0	129,6
29.09.2006	12:05 - 12:15	0,0	0,4	29.09.2006	12:15 - 12:25	128,0	130,4
29.09.2006	12:25 - 12:35	0,0	0,4	29.09.2006	12:35 - 12:45	129,2	130,4
29.09.2006	12:45 - 12:55	0,0	0,8	29.09.2006	12:55 - 13:05	128,4	129,6
29.09.2006	13:05 - 13:15	-0,4	0,8	29.09.2006	13:15 - 13:25	128,8	130,0
29.09.2006	13:25 - 13:35	-0,4	0,8	29.09.2006	13:35 - 13:45	128,8	130,4
29.09.2006	13:45 - 13:55	-0,4	0,8	29.09.2006	13:55 - 14:05	129,2	129,6
29.09.2006	14:05 - 14:15	0,0	0,8	29.09.2006	14:15 - 14:25	128,4	130,4
29.09.2006	14:25 - 14:35	0,0	0,8	29.09.2006	14:35 - 14:45	129,2	130,4
Number		20	20	Number		20	20
Average		0,1	0,5	Average		128,8	130,1
Standard deviation		0,3	0,3	Standard deviation		0,5	0,9

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#### 7.1 8.4.6 „Lack of fit“ (residual from the linear regression function)

*„lack of fit“ (residual from the linear regression function) 5 nmol/mol (equal to 5 ppb) at zero and ≤ 4 % from the measured value at concentrations higher than zero.*

#### 7.2 General requirements

The lack of fit of the analyzer shall be tested over the range between 0 % to 95 % of the maximum of the certification range using at least six concentrations (including the zero point). The analyzer shall be adjusted at a concentration of about 90 % of the maximum of the certification range. At each concentration (including zero) at least five individual readings shall be performed.

The concentrations shall be applied in the following sequence: 80 %, 40 %, 0 %, 60 %, 20 % and 95%. After each change in concentration at least four response times shall be taken into account before the next measurement is performed.

Calculation of the linear regression function and residuals shall be performed according to

Annex B (DIN EN 14212). All the (relative) residuals from the linear regression function shall fulfill the criteria.

The largest value of the relative residuals is reported as  $X_i$  and shall be taken into account in demonstrating compliance with type approval requirement 1. The value of the relative residual value at the level of the 1-hour emission limit value shall be taken in the calculation of type approval requirement 2 and 4.

Establishment of the regression line:

A linear regression function in the form of  $Y_i = A + B + X_i$  is made through calculation of the function

$$Y_i = a + B(X_i - X_z)$$

For the regression all measuring points (including zero) are taken into account. The total number of measuring points ( $n$ ) is equal to the number of concentration levels (at least six including zero) times the number of repetitions (at least five) at a particular concentration level.

The coefficient  $a$  is obtained from:

$$a = \sum Y_i / n$$

Where:

- $a$  is the average value of the  $Y$  – values;
- $Y_i$  is the individual  $Y$  – value;
- $N$  is the number of calibration points.

The coefficient  $B$  is obtained by:

$$B = \left( \sum Y_i (X_i - X_z) \right) / \sum (X_i - X_z)^2$$

Where:

- $X_z$  is the average of the  $X$  - values  $(= \sum (X_i / n))$ ;
- $X_i$  is the individual  $X$  – value.

The function  $Y_i = a + B (X_i - X_z)$  is converted to  $Y_i = A + B * X_i$  through the calculation of A:

$$A = a - B * X_z$$

The residuals of the averages of each calibration point (including the zero point) are calculated as follows:

The average of each calibration point (including the zero point) at one and the same concentration  $c$  is calculated according to:

$$(Y_a)_c = \sum (Y_i)_c / m$$

Where:

$(Y_a)_c$  is the average Y – value at concentration level  $c$ ;

$(Y_i)_c$  is the individual Y – value at concentration level  $c$ ;

$M$  is the number of repetitions and one and the same concentration level  $c$

The residual of each average ( $d_c$ ) at each concentration level  $c$  is calculated according to:

$$d_c = (Y_a)_c - (A + B \times c)$$

Each residual to a value relative to its own concentration level  $c$  is expressed as::

$$(d_r)_c = \frac{d_c}{c} \times 100\%$$

### 7.3 Performance of test

The test has been enforced regarding the specifications of the DIN EN 14212.

### 7.4 Evaluation

The following linear regressions were found:

The results of the average of the individual measurements are pictured in Figure 10 and Figure 11.

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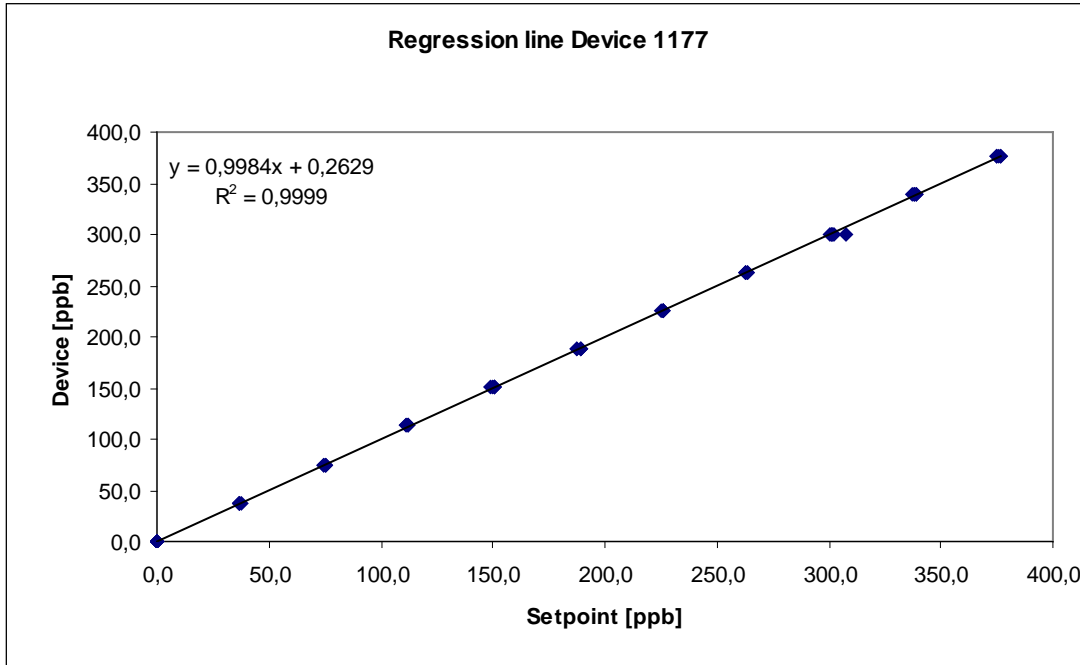


Figure 10: Linear regression function device 1 (1177)

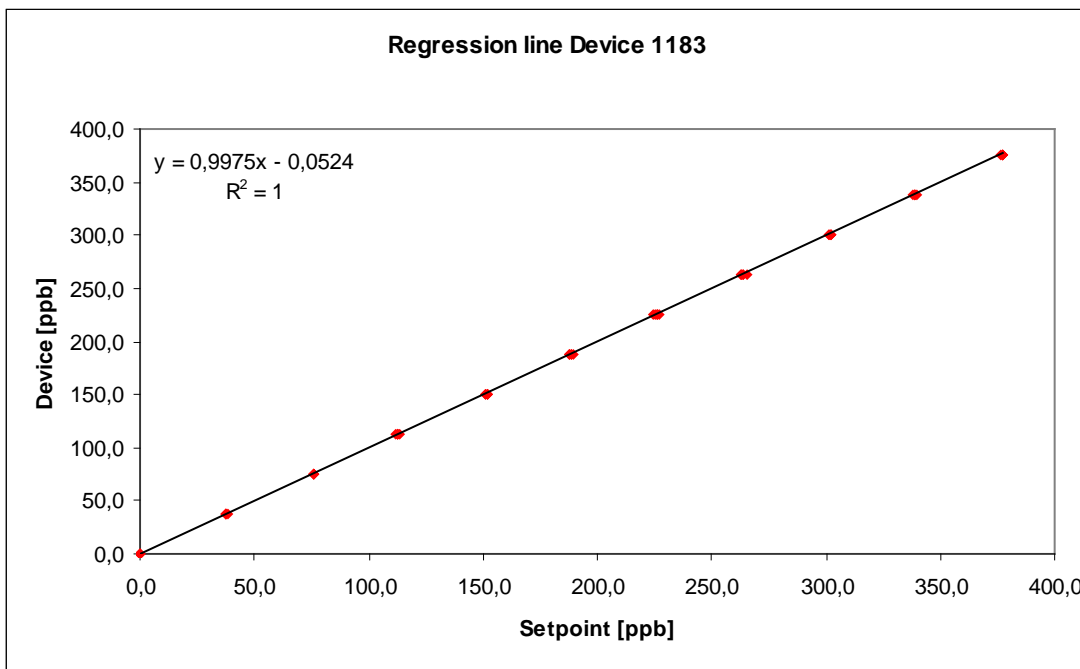


Figure 11: Linear regression function device 2 (1183)

The following linear regression functions have been determined:

Device 1 (1177):  $Y = 0,9984x + 0,2629$

Device 2 (1183):  $Y = 0,9975x - 0,0524$

The following deviations have been determined:

Table 9: Deviations from the desired values, device 1 (1177)

Testgas Setpoint [ppb]	Measured Value* [ppb]	Deviance** [ppb]	Permitted Deviance EN 14212 [ppb]	Deviance in % of measured value
0,0	0,3	0,3	5	----
37,6	37,3	-0,3	2	-0,8
75,2	75,0	-0,2	3	-0,3
112,8	111,9	-0,9	5	-0,8
150,4	150,0	-0,4	6	-0,3
188,0	188,2	0,2	8	0,1
225,6	225,7	0,1	9	0,0
263,2	263,1	-0,1	11	0,0
300,8	302,5	1,7	12	0,6
338,3	338,3	0,0	14	0,0
375,9	375,8	-0,1	15	0,0

\* Average of 5 individual measurements

\*\* Measured value minus Setpoint

Table 10: Deviations from the desired values, device 2 (1183)

Testgas Setpoint [ppb]	Measured Value* [ppb]	Deviance** [ppb]	Permitted Deviance EN 14212 [ppb]	Deviance in % of measured value
0,0	0,2	0,2	5	----
37,6	37,5	-0,1	2	-0,3
75,2	75,8	0,6	3	0,8
112,8	112,5	-0,3	5	-0,3
150,4	151,4	1,0	6	0,7
188,0	188,5	0,5	8	0,3
225,6	225,8	0,2	9	0,1
263,2	263,8	0,6	11	0,2
300,8	301,9	1,1	12	0,4
338,3	339,0	0,7	14	0,2
375,9	377,0	1,1	15	0,3

\* Average of 5 individual measurements

\*\* Measured value minus Setpoint

## 7.5 Assessment

For device 1 (1177) a deviation from the linear regression line of 0,3 ppb at zero and maximum -0,8 % of measured value at a concentrations higher than zero could be determined.

For device 2 (1183) a deviation from the linear regression line of 0,2 ppb at zero and maximum 0,9 % of measured value at a concentrations higher than zero could be determined.

The determined results fulfill the requirements of EN 14212.

Minimum requirement fulfilled? yes

## 7.6 Presentation of the test results

The single measured values are stated in Table 11 and Table 12.



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Table 11: Measured values „lack of fit“ test, device 1 (1177)

Cycle	Date	Time	Measured Value [ppb]	Setpoint [ppb]	Deviation [ppb]
1	25.09.2006	08:00 - 08:15	0,4	0,0	0,4
1	25.09.2006	09:15 - 09:30	37,2	37,6	-0,4
1	25.09.2006	08:30 - 08:45	75,2	75,2	0,0
1	25.09.2006	10:15 - 10:30	112,0	112,8	-0,8
1	25.09.2006	08:45 - 09:00	150,8	150,4	0,4
1	25.09.2006	09:45 - 10:00	188,8	188,0	0,8
1	25.09.2006	08:15 - 08:30	225,6	225,6	0,0
1	25.09.2006	10:30 - 10:45	263,6	263,2	0,4
1	25.09.2006	09:30 - 09:45	300,0	300,8	-0,8
1	25.09.2006	10:00 - 10:15	338,8	338,3	0,5
1	25.09.2006	09:00 - 09:15	376,4	375,9	0,5
2	25.09.2006	10:45 - 11:00	0,4	0,0	0,4
2	25.09.2006	12:00 - 12:15	37,2	37,6	-0,4
2	25.09.2006	11:15 - 11:30	74,8	75,2	-0,4
2	25.09.2006	13:00 - 13:15	111,6	112,8	-1,2
2	25.09.2006	11:30 - 11:45	150,4	150,4	0,0
2	25.09.2006	12:30 - 12:45	188,8	188,0	0,8
2	25.09.2006	11:00 - 11:15	226,0	225,6	0,4
2	25.09.2006	13:15 - 13:30	263,2	263,2	0,0
2	25.09.2006	12:15 - 12:30	301,2	300,8	0,4
2	25.09.2006	12:45 - 13:00	338,0	338,3	-0,3
2	25.09.2006	11:45 - 12:00	375,6	375,9	-0,3
3	25.09.2006	13:30 - 13:45	0,0	0,0	0,0
3	25.09.2006	14:45 - 15:00	37,2	37,6	-0,4
3	25.09.2006	14:00 - 14:15	75,2	75,2	0,0
3	25.09.2006	15:45 - 16:00	112,0	112,8	-0,8
3	25.09.2006	14:15 - 14:30	148,8	150,4	-1,6
3	25.09.2006	15:15 - 15:30	187,2	188,0	-0,8
3	25.09.2006	13:45 - 14:00	225,6	225,6	0,0
3	25.09.2006	16:00 - 16:15	263,6	263,2	0,4
3	25.09.2006	15:00 - 15:15	302,0	300,8	1,2
3	25.09.2006	15:30 - 15:45	339,2	338,3	0,9
3	25.09.2006	14:30 - 14:45	375,2	375,9	-0,7
4	26.09.2006	09:05 - 09:20	0,4	0,0	0,4
4	26.09.2006	10:20 - 10:35	37,2	37,6	-0,4
4	26.09.2006	09:35 - 09:50	75,2	75,2	0,0
4	26.09.2006	11:20 - 11:35	111,6	112,8	-1,2
4	26.09.2006	09:50 - 10:05	149,6	150,4	-0,8
4	26.09.2006	10:50 - 11:05	187,6	188,0	-0,4
4	26.09.2006	09:20 - 09:35	226,4	225,6	0,8
4	26.09.2006	11:35 - 11:50	262,4	263,2	-0,8
4	26.09.2006	10:35 - 10:50	301,6	300,8	0,8
4	26.09.2006	11:05 - 11:20	338,4	338,3	0,1
4	26.09.2006	10:05 - 10:20	375,2	375,9	-0,7
5	26.09.2006	11:50 - 12:05	0,4	0,0	0,4
5	26.09.2006	13:05 - 13:20	37,6	37,6	0,0
5	26.09.2006	12:20 - 12:35	74,8	75,2	-0,4
5	26.09.2006	14:05 - 14:20	112,4	112,8	-0,4
5	26.09.2006	12:35 - 12:50	150,4	150,4	0,0
5	26.09.2006	13:35 - 13:50	188,8	188,0	0,8
5	26.09.2006	12:05 - 12:20	224,8	225,6	-0,8
5	26.09.2006	14:20 - 14:35	262,8	263,2	-0,4
5	26.09.2006	13:20 - 13:35	307,6	300,8	6,8
5	26.09.2006	13:50 - 14:05	337,2	338,3	-1,1
5	26.09.2006	12:50 - 13:05	376,4	375,9	0,5

Table 12: Measured values „lack of fit“ test, device 2 (1183)

Cycle	Date	Time	Measured Value [ppb]	Setpoint [ppb]	Deviation [ppb]
1	25.09.2006	08:00 - 08:15	0,0	0,0	0,0
1	25.09.2006	09:15 - 09:30	37,6	37,6	0,0
1	25.09.2006	08:30 - 08:45	76,0	75,2	0,8
1	25.09.2006	10:15 - 10:30	112,8	112,8	0,0
1	25.09.2006	08:45 - 09:00	151,2	150,4	0,8
1	25.09.2006	09:45 - 10:00	188,0	188,0	0,0
1	25.09.2006	08:15 - 08:30	226,4	225,6	0,8
1	25.09.2006	10:30 - 10:45	265,2	263,2	2,0
1	25.09.2006	09:30 - 09:45	302,0	300,8	1,2
1	25.09.2006	10:00 - 10:15	339,2	338,3	0,9
1	25.09.2006	09:00 - 09:15	377,2	375,9	1,3
2	25.09.2006	10:45 - 11:00	0,4	0,0	0,4
2	25.09.2006	12:00 - 12:15	37,6	37,6	0,0
2	25.09.2006	11:15 - 11:30	75,6	75,2	0,4
2	25.09.2006	13:00 - 13:15	111,6	112,8	-1,2
2	25.09.2006	11:30 - 11:45	151,6	150,4	1,2
2	25.09.2006	12:30 - 12:45	189,6	188,0	1,6
2	25.09.2006	11:00 - 11:15	226,4	225,6	0,8
2	25.09.2006	13:15 - 13:30	263,2	263,2	0,0
2	25.09.2006	12:15 - 12:30	302,0	300,8	1,2
2	25.09.2006	12:45 - 13:00	340,0	338,3	1,7
2	25.09.2006	11:45 - 12:00	376,0	375,9	0,1
3	25.09.2006	13:30 - 13:45	0,0	0,0	0,0
3	25.09.2006	14:45 - 15:00	37,2	37,6	-0,4
3	25.09.2006	14:00 - 14:15	75,6	75,2	0,4
3	25.09.2006	15:45 - 16:00	112,4	112,8	-0,4
3	25.09.2006	14:15 - 14:30	151,6	150,4	1,2
3	25.09.2006	15:15 - 15:30	188,0	188,0	0,0
3	25.09.2006	13:45 - 14:00	224,4	225,6	-1,2
3	25.09.2006	16:00 - 16:15	264,0	263,2	0,8
3	25.09.2006	15:00 - 15:15	301,6	300,8	0,8
3	25.09.2006	15:30 - 15:45	338,8	338,3	0,5
3	25.09.2006	14:30 - 14:45	377,6	375,9	1,7
4	26.09.2006	09:05 - 09:20	0,0	0,0	0,0
4	26.09.2006	10:20 - 10:35	38,0	37,6	0,4
4	26.09.2006	09:35 - 09:50	76,0	75,2	0,8
4	26.09.2006	11:20 - 11:35	112,4	112,8	-0,4
4	26.09.2006	09:50 - 10:05	150,8	150,4	0,4
4	26.09.2006	10:50 - 11:05	188,4	188,0	0,4
4	26.09.2006	09:20 - 09:35	226,8	225,6	1,2
4	26.09.2006	11:35 - 11:50	262,8	263,2	-0,4
4	26.09.2006	10:35 - 10:50	302,4	300,8	1,6
4	26.09.2006	11:05 - 11:20	339,2	338,3	0,9
4	26.09.2006	10:05 - 10:20	377,2	375,9	1,3
5	26.09.2006	11:50 - 12:05	0,4	0,0	0,4
5	26.09.2006	13:05 - 13:20	37,2	37,6	-0,4
5	26.09.2006	12:20 - 12:35	76,0	75,2	0,8
5	26.09.2006	14:05 - 14:20	113,2	112,8	0,4
5	26.09.2006	12:35 - 12:50	151,6	150,4	1,2
5	26.09.2006	13:35 - 13:50	188,4	188,0	0,4
5	26.09.2006	12:05 - 12:20	225,2	225,6	-0,4
5	26.09.2006	14:20 - 14:35	263,6	263,2	0,4
5	26.09.2006	13:20 - 13:35	301,6	300,8	0,8
5	26.09.2006	13:50 - 14:05	337,6	338,3	-0,7
5	26.09.2006	12:50 - 13:05	377,2	375,9	1,3

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### 7.1 8.4.7 Sensitivity coefficient to sample gas pressure

*The sensitivity coefficient to sample gas pressure have to constitute  $\leq 3,0$  nmol/mol/kPa (equal to 3,0 ppb).*

### 7.2 General requirement

Measurements are taken at a concentration of about 70 % to 80 % of the maximum of the certification range at an absolute pressure of 80 kPa  $\pm$  0,2 kPa and at an absolute pressure of 110 kPa  $\pm$  0,2 kPa. At each pressure after waiting the time equivalent to one independent reading three individual measurements are recorded. From these 3 measurements the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

The sample gas pressure influence is calculated by:

$$b_{sp} = \left| \frac{(C_{P1} - C_{P2})}{(P_2 - P_1)} \right|$$

Where:

$b_{sp}$  is the sample gas pressure influence (nmol/mol/kPa);

$C_{P1}$  is the average concentration of the measurements at sampling gas pressure  $P_1$  (nmol/mol);

$C_{P2}$  is the average concentration of the measurements at sampling gas pressure  $P_2$  (nmol/mol);

$P_1$  is the sampling gas pressure  $P_1$  (kPa);

$P_2$  is the sampling gas pressure  $P_2$  (kPa).

$b_{sp}$  shall comply with the performance criterion.

### 7.3 Performance of test

The M100E analyzer determines the concentration of SO<sub>2</sub> in a sample gas drawn through the instrument. It is equipped with a pump and sucks the requires sample gas in (approx. 0,7 l/min). These pump has to work against the ambient pressure. This means that the ambient pressure on sample inlet and behind the pump is equal. The obsessive induce of a over- or under pressure in these system could destroy the analyzer. It is required that test gas is given without pressure and abundant through the analyzer. The abounding gas drained off by a T-valve.

During the 3-month field test the ambient pressure conditions changed between 982 mbar and 1031 mbar. During the investigations no influence on ambient air pressure changes could be determined.

By running the analyzer with 5 sample gas filters at the same time it was tested how the analyzer reacts to a blocked sample gas filter no influence could be determined.

#### 7.4 Evaluation

Due to the assembling of the analyzer the sensitivity coefficient to sample gas pressure could not be determined repeatable without the risk of a demolition of the analyzer. During the field test no influence of the ambient air pressure in the range of 982 mbar and 1031 mbar could be determined.

The lowest ambient pressure during the field test has been measured on March 01 with 982 mbar (98,2 kPa). At the daily test gas giving (according to VDI 4202) a value of 41,5 µg/m<sup>3</sup> (equal to 15,6 ppb SO<sub>2</sub>) for device 1 (1177) and 40,2 µg/m<sup>3</sup> (equal to 15,1 ppb SO<sub>2</sub>) for device 2 (1183) has been measured.

The highest ambient pressure during the field test has been measured on March 12 with 1031 mbar (103,1 kPa). At the daily test gas giving (according to VDI 4202) a value of 41,8 µg/m<sup>3</sup> (equal to 15,7 ppb SO<sub>2</sub>) for device 1 (1177) and 41,0 µg/m<sup>3</sup> (equal to 15,4 ppb SO<sub>2</sub>) for device 2 (1183) has been measured.

Hence the following coefficient to sample gas pressure  $b_{gp}$  have been determined:

$$b_{gp} \text{ Device 1177} = 0,02 \text{ ppb/kPa}$$

$$b_{gp} \text{ Device 1183} = 0,06 \text{ ppb/kPa}$$

#### 7.5 Assessment

The sensitivity coefficient to sample gas pressure is lower than the allowed value of in maximum 3 ppb/kPa . The measured values of 0,02 ppb/kPa for device 1 (1177) and 0,06 ppb/kPa for device 2 (1183) are used for the calculation of the total uncertainty.

Minimum requirement fulfilled? yes

#### 7.6 Presentation of test results

Here not applicable.

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### 7.1 8.4.8 Sensitivity coefficient to sample gas temperature

*The sensitivity coefficient to sample gas temperature have to constitute  $\leq 1,0$  nmol/mol/K (equal to 1,0 ppp/K).*

### 7.2 General requirement

For the determination of the dependence of the sample gas temperature measurements shall be performed at sample gas temperatures of  $T_1 = 0$  °C and  $T_2 = 30$ °C. The temperature dependence shall be determined at a concentration of about 70 % to 80 % of the maximum of the certification range. Wait the time equivalent to one independent and record 3 individual measurements at each temperature.

The sample gas temperature, measured at the inlet of the analyzer, shall be held constant for at least 30 min.

The influence of sample gas temperature is calculated from:

$$b_{gt} = \frac{(C_{T2} - C_{T1})}{(T_2 - T_1)}$$

Where:

$b_{gt}$  is the sample gas temperature influence (nmol/mol/°C);

$C_{T1}$  is the average concentration of the measurements at sample gas temperature  $T_1$  (°C);

$C_{T2}$  is the average concentration of the measurements at sample gas temperature  $T_2$  (°C);

$T_1$  is the sample gas temperature  $T_1$  (°C);

$T_2$  is the sample gas temperature  $T_2$  (°C).

$b_{gt}$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212.

The test gas system has been positioned inside of a climate chamber. The test gas was offered through an 20 m long conditioned sample gas line to the analyzers, which were positioned directly in front of the climate chamber. The test was done with 0 °C and with 30 °C.

#### 7.4 Evaluation

The following coefficient to sample gas temperature has been determined:

$$b_{gt} \text{ Device 1 (1177)} = -0,0133 \text{ ppb/K}$$

$$b_{gt} \text{ Device 2 (1183)} = 0,0133 \text{ ppb/K}$$

#### 7.5 Assessment

The sensitivity coefficient of the sample gas temperature  $b_{gt}$  is with -0,0133 ppb/K for device 1 (1177) and 0,0133 ppb/K for device 2 (1183) smaller than the required value of 1 ppb/K.

Minimum requirement fulfilled? yes

#### 7.6 Presentation of test results

The measured values are to see in Table 13.

Table 13: Measured values of determination of the sensitivity coefficient of sample gas temperature

Date	Time	Span Point		
		Temperature	Device 1 (1177)	Device 2 (1183)
		[°C]	[ppb]	[ppb]
07.02.2007	08:15 - 08:20	0	290,0	289,6
07.02.2007	08:20 - 08:25	0	289,6	290,4
07.02.2007	08:25 - 08:30	0	290,8	290,4
	<b>Average</b>	<b>C<sub>T1</sub></b>	<b>290,1</b>	<b>290,1</b>
07.02.2007	13:20 - 13:25	30	290,0	290,4
07.02.2007	13:25 - 13:30	30	290,0	290,4
07.02.2007	13:30 - 13:35	30	289,2	290,8
	<b>Average</b>	<b>C<sub>T2</sub></b>	<b>289,7</b>	<b>290,5</b>

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## 7.1 8.4.9 Sensitivity coefficient to the surrounding temperature

*Sensitivity coefficient to the surrounding temperature has to constitute  $\leq 1,0$  nmol/mol/K (equal to 1,0 ppb/K)*

## 7.2 General requirement

The influence of the surrounding temperature shall be determined at the following temperatures (within the specifications of the manufacturer:

- 1) at the minimum temperature  $T_{\min} = 273$  K;
- 2) at the laboratory temperature  $T_1 = 293$  K;
- 3) at the maximum temperature  $T_{\max} = 303$  K;

For this tests a climate chamber is necessary.

The influence shall be determined at a concentration around 70 % to 80 % of the maximum of the certification range. At each temperature setting after waiting the time equivalent to one independent reading three individual measurements at zero and at span shall be recorded.

The measurements shall be performed in the following sequence of the temperature settings:

$T_1, T_{\min}, T_1$  und  $T_1, T_{\max}, T_1$

At the first temperature ( $T_{\text{lab}}$ ) the analyzer shall be adjusted at zero and at span level (70 % to 80 % of the maximum of the certification range). Then three individual measurements are recorded after waiting the time equivalent to one independent reading at  $T_1$ , at  $T_{\min}$  and again at  $T_{\text{lab}}$ . This procedure shall be repeated at the temperature sequence of  $T_{\text{lab}}, T_{\max}$ , and at  $T_{\text{lab}}$ .

In order to exclude any possible drift due to factors other than temperature, the measurements at  $T_{\text{lab}}$  are averaged, which is taken into account in the following formula for calculation of the surrounding air temperature dependence:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T - T_1} \right|$$

Where:

- $b_{st}$  is the surrounding air temperature dependence at zero or span and at  $T_{\min}$  or  $T_{\max}$  ( $\mu\text{mol/mol}/^\circ\text{C}$ );
- $x_T$  is the average of the measurements at  $T_{\min}$  or  $T_{\max}$  (ppb);
- $x_1$  is the first average of the measurements at  $T_{\text{lab}}$  just after calibration (ppb);
- $x_2$  is the second of the measurements at  $T_{\text{lab}}$  just before calibration (ppb);
- $T_1$  is the surrounding air temperature at the laboratory (K);
- $T$  is the surrounding air temperature  $T_{\min}$  or  $T_{\max}$  (K).

For reporting the surrounding air temperature dependence the highest value is taken of the two calculations of the temperature dependence at  $T_{\min}$  and  $T_{\max}$ .

$b_{st}$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212.

### 7.4 Evaluation

The following sensitivity coefficients to the surrounding temperature have been determined:

Table 14: Sensitivity coefficient at zero for device 1177

	T [°C]	Average Device 1177 [ppb]	determined $b_{st}$ [ppb/K]	allowed $b_{st}$ [ppb/K]	Criteria fulfilled? EN 14212
$T_1$	20	0,40			
$T_{\min}$	0	-0,13	0,02	1	Yes
$T_1$	20	0,27			
$T_1$	20	0,27			
$T_{\max}$	30	0,67	0,04	1	Yes
$T_1$	20	0,27			

Table 15: Sensitivity coefficient at zero for device 1183

	T [°C]	Average Device 1183 [ppb]	determined $b_{st}$ [ppb/K]	allowed $b_{st}$ [ppb/K]	Criteria fulfilled? EN 14212
$T_1$	20	0,13			
$T_{\min}$	0	0,40	0,00	1	Yes
$T_1$	20	0,53			
$T_1$	20	0,53			
$T_{\max}$	30	0,67	0,01	1	Yes
$T_1$	20	0,53			

The sensitivity coefficients at zero are stated in Table 14 and Table 15. The results fulfill the performance criteria of EN 14212.



Table 16: Sensitivity coefficient at span for device 1177

	T [°C]	Average Device 1177 [ppb]	determined b <sub>st</sub> [ppb/K]	allowed b <sub>st</sub> [ppb/K]	Criteria fulfilled? EN 14212
T <sub>1</sub>	20	290,27			
T <sub>min</sub>	0	290,13	0,01	1	Yes
T <sub>1</sub>	20	290,40			
T <sub>1</sub>	20	290,40			
T <sub>max</sub>	30	290,93	0,05	1	Yes
T <sub>1</sub>	20	290,53			

Table 17: Sensitivity coefficient at span for device 1183

	T [°C]	Average Device 1183 [ppb]	determined b <sub>st</sub> [ppb/K]	allowed b <sub>st</sub> [ppb/K]	Criteria fulfilled? EN 14212
T <sub>1</sub>	20	290,93			
T <sub>min</sub>	0	290,67	0,00	1	Yes
T <sub>1</sub>	20	290,40			
T <sub>1</sub>	20	290,40			
T <sub>max</sub>	30	290,13	0,03	1	Yes
T <sub>1</sub>	20	290,53			

The sensitivity coefficients at span are stated in Table 16 and Table 17. The results fulfill the performance criteria of EN 14212.

## 7.5 Assessment

The sensitivity coefficient of the surrounding temperature b<sub>st</sub> does not exceed the performance criteria of maximum 1,0 ppb/K. The largest coefficients b<sub>st</sub> in each case, 0,05 ppb/K for device 1 (1177) and 0,03 ppb/K for device 2 (1183), have been taken for the calculation of the total uncertainty.

Minimum requirement fulfilled ? yes

## 7.6 Presentation of test results

The measured values are stated in Table 18.

Table 18: Measured values of determination of the sensitivity coefficient of surrounding temperature

Date	Zero Point				Zero Point			
	Time	Temperature	Device 1 (1177)	Device 2 (1183)	Time	Temperature	Device 1 (1177)	Device 2 (1183)
		[°C]	[ppb]	[ppb]		[°C]	[ppb]	[ppb]
02.02.2007	09:45 - 09:50	20	0,00	0,00	09:50 - 09:55	20	290,0	290,4
02.02.2007	09:55 - 10:00	20	0,40	0,40	10:00 - 10:05	20	290,8	291,2
02.02.2007	10:05 - 10:10	20	0,80	0,00	10:10 - 10:15	20	290,0	291,2
	<b>Average</b>		<b>0,40</b>	<b>0,13</b>	<b>Average</b>		<b>290,3</b>	<b>290,9</b>
05.02.2007	08:05 - 08:10	0	0,40	0,00	08:10 - 08:15	0	289,6	291,6
05.02.2007	08:15 - 08:20	0	-0,40	0,80	08:20 - 08:25	0	290,4	290,0
05.02.2007	08:25 - 08:30	0	-0,40	0,40	08:30 - 08:35	0	290,4	290,4
	<b>Average</b>		<b>-0,13</b>	<b>0,40</b>	<b>Average</b>		<b>290,1</b>	<b>290,7</b>
05.02.2007	12:40 - 12:45	20	0,40	0,40	12:45 - 12:50	20	290,4	289,6
05.02.2007	12:50 - 12:55	20	0,00	0,80	12:55 - 13:00	20	289,6	290,0
05.02.2007	13:00 - 13:05	20	0,40	0,40	13:05 - 13:10	20	291,2	291,6
	<b>Average</b>		<b>0,27</b>	<b>0,53</b>	<b>Average</b>		<b>290,4</b>	<b>290,4</b>
05.02.2007	17:30 - 17:35	30	0,80	0,40	17:35 - 17:40	30	290,4	291,2
05.02.2007	17:40 - 17:45	30	0,40	0,80	17:45 - 17:50	30	291,2	289,6
05.02.2007	17:50 - 17:55	30	0,80	0,80	17:55 - 18:00	30	291,2	289,6
	<b>Average</b>		<b>0,67</b>	<b>0,67</b>	<b>Average</b>		<b>290,9</b>	<b>290,1</b>
06.02.2007	08:00 - 08:05	20	0,40	0,40	08:05 - 08:10	20	290,4	290,4
06.02.2007	08:10 - 08:15	20	0,00	0,40	08:15 - 08:20	20	291,2	290,8
06.02.2007	08:20 - 08:25	20	0,40	0,80	08:25 - 08:30	20	290,0	290,4
	<b>Average</b>		<b>0,27</b>	<b>0,53</b>	<b>Average</b>		<b>290,5</b>	<b>290,5</b>

### 7.1 8.4.10 Sensitivity coefficient to electrical voltage

*Sensitivity coefficient to the electrical voltage  $\leq 0,30$  nmol/mol/V (equal to 0,30 ppb/V)*

### 7.2 General requirement

The sensitivity coefficient of electrical voltage shall be determined at both ends of the specified voltage range,  $V_{\min}$  and  $V_{\max}$  at zero concentration and at a concentration around 70 % to 80 % of the maximum of the certification range. After waiting the time equivalent to one independent reading three individual measurements at each voltage and concentration level shall be recorded.

The voltage dependence is calculated according to the EN 14212 as follows:

$$b_v = \frac{(C_{V_2} - C_{V_1})}{(V_2 - V_1)}$$

Where:

$b_v$  is the voltage influence ( $\mu\text{mol/mol/V}$ );

$C_{V_1}$  is the average concentration reading of the measurements at voltage  $V_1$  (nmol/mol);

$C_{V_2}$  is the average concentration reading of the measurements at voltage  $V_2$  (nmol/mol);

$V_1$  is the minimum voltage  $V_{\min}$  (V) specified by the manufacturer;

$V_2$  is the maximum voltage  $V_{\max}$  (V) specified by the manufacturer.

For an analyzer operating on direct current the type approval test of voltage variation shall be carried out over the range of  $\pm 10$  % of the nominal voltage.

$b_v$  shall comply with the performance criterion.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212. For the test a transformer was switched between the power supply and the analyzers. For the test zero and span gas was offered at the different voltages to the analyzers.

### 7.4 Evaluation

The following sensitivity coefficients to electrical voltage have been determined:

$b_v$  Device 1177 NP: -0,01 (ppb/V)

$b_v$  Device 1177 RP: 0,00 (ppb/V)

$b_v$  Device 1183 NP: -0,01 (ppb/V)

$b_v$  Device 1183 RP: 0,02 (ppb/V)

## 7.5 Assessment

The sensitivity coefficient to electrical voltage  $b_v$  does not exceed the performance criteria of maximum 0,30 ppb/V according to EN 14212. The largest coefficients  $b_v$  in each case -0,01 ppb/V for device 1 (1177) and 0,02 ppb/V for device 2 (1183) have been taken for the calculation of the total uncertainty.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values of determination of the sensibility coefficient to electrical voltage are stated in Table 19 and Table 20.

Table 19: Measured values of determination of the sensitivity coefficient to electrical voltage at zero

Date	Time	Device 1 (1177)	Device 2 (1183)
		[ppb]	[ppb]
<b>Zero Gas bei 210 V</b>			
10.01.2007	15:05 - 15:15	0,4	0,0
10.01.2007	15:25 - 15:35	0,4	0,4
10.01.2007	15:45 - 15:55	0,4	0,4
<b>Average</b>		<b>0,4</b>	<b>0,3</b>
<b>Zero Gas bei 245 V</b>			
10.01.2007	16:15 - 16:25	0,0	-0,4
10.01.2007	16:35 - 16:45	0,0	-0,4
10.01.2007	16:55 - 17:05	0,4	0,4
<b>Average</b>		<b>0,1</b>	<b>-0,1</b>

Table 20: Measured values of determination of the sensitivity coefficient to electrical voltage at span

Date	Time	Device 1 (1177)	Device 2 (1183)
		[ppb]	[ppb]
<b>Span Gas bei 210 V</b>			
10.01.2007	15:15 - 15:25	274,0	276,0
10.01.2007	15:35 - 15:45	274,8	275,6
10.01.2007	15:55 - 16:05	275,6	276,0
<b>Average</b>		<b>274,8</b>	<b>275,9</b>
<b>Span Gas bei 245 V</b>			
10.01.2007	16:25 - 16:35	275,2	276,0
10.01.2007	16:45 - 16:55	274,8	276,8
10.01.2007	17:05 - 17:15	274,0	276,8
<b>Average</b>		<b>274,7</b>	<b>276,5</b>

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## 7.1 8.4.11 Interferences

*Interferences at zero and the concentration  $c_t$  (at the level of the 1-hour limit value). The allowed deviation for the measured component H<sub>2</sub>O and m-Xylol is at  $\leq 10$  nmol/mol (equal to 10 ppb) for the components H<sub>2</sub>S, NH<sub>3</sub>, NO and NO<sub>2</sub>  $\leq 5,0$  nmol/mol (equal tot 5 ppb).*

## 7.2 General requirement

The analyzer response to certain interferents, which are expected to be present in ambient air, shall be tested. The interferents can give a positive or negative response. The test shall be performed at zero and at a test concentration ( $c_t$ ) similar to the 1-hour limit value.

The concentration of the mixtures of the test gases with the interferent shall have an uncertainty of less than 5 % and shall be traceable to national standards. The interferents to be tested and their respective concentrations are given in Table 21. The influence of each interferent shall be determined separately. A correction of the concentration of the measurand shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyzer at zero and span level the analyzer shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration as given in Table 21. With this mixture one independent measurement followed by two individual measurements shall be carried out. This procedure shall be repeated with a mixture of the measurand at concentration  $c_t$  and the interferent to be investigated. The influence quantity at zero and concentration  $c_t$  are calculated from:

$$X_{\text{int},z} = x_z$$

$$X_{\text{int},c_t} = x_{c_t} - c_t$$

Where:

$X_{\text{int},z}$  is the influence quantity of the interferent at zero (nmol/mol);

$x_z$  is the average of the measurements at zero (nmol/mol);

$X_{\text{int},c_t}$  is the influence quantity of the interferent at concentration  $c_t$  (nmol/mol);

$x_{c_t}$  is the average of the measurements at concentration  $c_t$  (nmol/mol);

$c_t$  is the concentration of the applied gas at the level of the 1-hour limit value ( $\mu\text{mol/mol}$ ).

The influence quantity of the interferences shall comply with the performance criteria, both at zero and at concentration  $c_t$ .

## 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212. The analyzers have been adjusted at zero and the concentration  $c_t$  (130 ppb). Afterward zero and span gas mixtures including the different interference gases have been given through the analyzers. The interfering components and concentrations are stated in Table 21 have been used.

Table 21: Interfering components regarding EN 14212

Interferences	Concentration
H <sub>2</sub> O	19 mmol/mol
H <sub>2</sub> S	200 nmol/mol
NH <sub>3</sub>	200 nmol/mol
NO	500 nmol/mol
NO <sub>2</sub>	200 nmol/mol
m-Xylol	1 µmol/mol

#### 7.4 Evaluation

The following responses to interfering components have been determined.

 Table 22: Influence of the tested interfering components ( $c_t = 130$  ppb)

		Device 1 (1177) [ppb]	Device 2 (1183) [ppb]
<b>H<sub>2</sub>O</b>	X <sub>z</sub>	-0,4	-0,1
	<b>X<sub>int,z</sub></b>	<b>-0,4</b>	<b>-0,1</b>
	x <sub>ct</sub>	128,3	128,4
	<b>X<sub>int,ct</sub></b>	<b>-1,7</b>	<b>-1,6</b>
Maximum allowed deviance		10	10
fulfilled?		<b>yes</b>	<b>yes</b>
<b>H<sub>2</sub>S</b>	X <sub>z</sub>	0,3	0,4
	<b>X<sub>int,z</sub></b>	<b>0,3</b>	<b>0,4</b>
	x <sub>ct</sub>	130,9	130,4
	<b>X<sub>int,ct</sub></b>	<b>0,9</b>	<b>0,4</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>NH<sub>3</sub></b>	X <sub>z</sub>	0,3	0,3
	<b>X<sub>int,z</sub></b>	<b>0,3</b>	<b>0,3</b>
	x <sub>ct</sub>	130,1	131,1
	<b>X<sub>int,ct</sub></b>	<b>0,1</b>	<b>1,1</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>NO</b>	X <sub>z</sub>	0,5	0,4
	<b>X<sub>int,z</sub></b>	<b>0,5</b>	<b>0,4</b>
	x <sub>ct</sub>	133,2	132,9
	<b>X<sub>int,ct</sub></b>	<b>3,2</b>	<b>2,9</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>NO<sub>2</sub></b>	X <sub>z</sub>	0,0	0,1
	<b>X<sub>int,z</sub></b>	<b>0,0</b>	<b>0,1</b>
	x <sub>ct</sub>	130,5	130,8
	<b>X<sub>int,ct</sub></b>	<b>0,5</b>	<b>0,8</b>
Maximum allowed deviance		5	5
fulfilled?		<b>yes</b>	<b>yes</b>
<b>m-Xylol</b>	X <sub>z</sub>	0,0	0,3
	<b>X<sub>int,z</sub></b>	<b>0,0</b>	<b>0,3</b>
	x <sub>ct</sub>	131,2	130,9
	<b>X<sub>int,ct</sub></b>	<b>1,2</b>	<b>0,9</b>
Maximum allowed deviance		10	10
fulfilled?		<b>yes</b>	<b>yes</b>

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## 7.5 Assessment

The responses to the interfering components H<sub>2</sub>O, H<sub>2</sub>S, NH<sub>3</sub>, NO, NO<sub>2</sub> and m-Xylol do not exceed the performance criteria of EN 14212.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values are stated in Table 23.

Table 23: Measured values of the interference test

Date	Time	Device 1 (1177)	Device 2 (1183)	Date	Time	Device 1 (1177)	Device 2 (1183)
		[ppb]	[ppb]			[ppb]	[ppb]
<b>Zero Gas + H<sub>2</sub>O</b>				<b>Zero Gas + NO</b>			
17.01.2007	07:15 - 07:25	-0,4	0,0	17.01.2007	11:00 - 11:10	0,4	0,4
17.01.2007	07:35 - 07:45	-0,8	-0,4	17.01.2007	11:20 - 11:30	0,4	0,4
17.01.2007	07:55 - 08:05	0,0	0,0	17.01.2007	11:40 - 11:50	0,8	0,4
<b>Average</b>		<b>-0,4</b>	<b>-0,1</b>	<b>Average</b>		<b>0,5</b>	<b>0,4</b>
<b>Span Gas + H<sub>2</sub>O</b>				<b>Span Gas + NO</b>			
17.01.2007	07:25 - 07:35	128,8	128,4	17.01.2007	11:10 - 11:20	132,4	132,8
17.01.2007	07:45 - 07:55	128,4	128,0	17.01.2007	11:30 - 11:40	133,6	132,8
17.01.2007	08:05 - 08:15	127,6	128,8	17.01.2007	11:50 - 12:00	133,6	133,2
<b>Average</b>		<b>128,3</b>	<b>128,4</b>	<b>Average</b>		<b>133,2</b>	<b>132,9</b>
<b>Zero Gas + H<sub>2</sub>S</b>				<b>Zero Gas + NO<sub>2</sub></b>			
17.01.2007	08:35 - 08:45	0,0	0,4	17.01.2007	12:40 - 12:50	0,0	0,0
17.01.2007	08:55 - 08:05	0,4	0,4	17.01.2007	13:00 - 13:10	0,0	0,4
17.01.2007	09:15 - 09:25	0,4	0,4	17.01.2007	13:20 - 13:30	0,0	0,0
<b>Average</b>		<b>0,3</b>	<b>0,4</b>	<b>Average</b>		<b>0,0</b>	<b>0,1</b>
<b>Span Gas + H<sub>2</sub>S</b>				<b>Span Gas + NO<sub>2</sub></b>			
17.01.2007	08:45 - 08:55	131,2	130,0	17.01.2007	12:50 - 13:00	130,4	130,8
17.01.2007	09:05 - 09:15	130,8	130,4	17.01.2007	13:10 - 13:20	130,0	131,2
17.01.2007	09:25 - 09:35	130,8	130,8	17.01.2007	13:30 - 13:40	131,2	130,4
<b>Average</b>		<b>130,9</b>	<b>130,4</b>	<b>Average</b>		<b>130,5</b>	<b>130,8</b>
<b>Zero Gas + NH<sub>3</sub></b>				<b>Zero Gas + m-Xylol</b>			
17.01.2007	09:40 - 09:50	0,4	0,0	17.01.2007	13:55 - 14:05	0,0	0,4
17.01.2007	10:00 - 10:10	0,4	0,4	17.01.2007	14:15 - 14:25	0,0	0,4
17.01.2007	10:20 - 10:30	0,0	0,4	17.01.2007	14:35 - 14:45	0,0	0,0
<b>Average</b>		<b>0,3</b>	<b>0,3</b>	<b>Average</b>		<b>0,0</b>	<b>0,3</b>
<b>Span Gas + NH<sub>3</sub></b>				<b>Span Gas + m-Xylol</b>			
17.01.2007	09:50 - 10:00	130,4	131,2	17.01.2007	14:05 - 14:15	130,8	130,4
17.01.2007	10:10 - 10:20	130,0	131,2	17.01.2007	14:25 - 14:35	131,2	131,2
17.01.2007	10:30 - 10:40	130,0	130,8	17.01.2007	14:45 - 14:55	131,6	131,2
<b>Average</b>		<b>130,1</b>	<b>131,1</b>	<b>Average</b>		<b>131,2</b>	<b>130,9</b>

## 7.1 8.4.12 Average test

*The average effect has to constitute  $\leq 7\%$  of the measured value.*

## 7.2 General requirement

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyzer. In general the output of an analyzer is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging the following concentrations are applied to the analyzer and readings are taken at each concentration:

A stepwise varied concentration of SO<sub>2</sub> between zero and concentration  $c_t$  (70 % to 80 % of the maximum of the certification range)

The time period ( $t_c$ ) of the constant SO<sub>2</sub> concentration shall be at least equal to a period necessary to obtain four independent readings (which equals to at least sixteen response times). The time period ( $t_v$ ) of the varying SO<sub>2</sub> concentration shall be at least equal to a period to obtain four independent readings. The time period ( $t_{SO_2}$ ) for the SO<sub>2</sub> concentration shall be 45 s followed by a period ( $t_{zero}$ ) of 45 s of zero concentration.

Further:

$c_t$  is the test concentration (nmol/mol);

$t_v$  is a whole number of  $t_{SO_2}$  and  $t_{zero}$  pairs, and contains a minimum of 3 such pairs.

The change from  $t_{SO_2}$  to  $t_{zero}$  shall be within 0,5 s. The change from  $t_c$  to  $t_v$  shall be within one response time of the analyzer under test.

The averaging effect ( $X_{av}$ ) is calculated according to:

$$X_{av} = \frac{C_{const}^{av} - 2C_{var}^{av}}{C_{const}^{av}} * 100$$

Where:

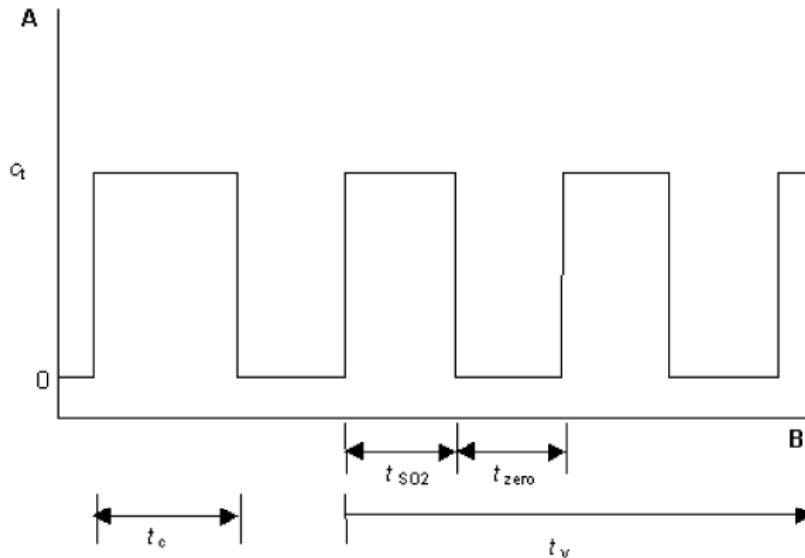
$X_{av}$  is the averaging effect (%);

$C_{const}^{av}$  is the average of the at least four independent measurements during the constant concentration period ( $t_c$ ) (nmol/mol);

$C_{var}^{av}$  is the average of the at least four independent measurements during the variable concentration period ( $t_v$ ) (nmol/mol).



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**Key**

- A Concentration (nmol/mol)
- B Time

Figure 12: Concentration variations for the averaging effect test ( $t_{SO_2} = t_{zero} = 45 \text{ s.}$ )

**7.3 Performance of test**

The test has been enforced regarding the specifications of EN 14212. At first a constant SO<sub>2</sub> concentration has been applied to the analyzers and an average value was calculated. After this a varied concentration of SO<sub>2</sub> between zero and the concentration  $c_t$  has been applied to the analyzer. With the help of a 3-way valve the concentration was changed every 45 s. During the time of varying concentrations an average value has been calculated.

**7.4 Evaluation**

In The following average has been calculated:

constant average		variable average	
Device 1 (1177)	298,2 ppb	Device 1 (1177)	145,6 ppb
Device 2 (1183)	296,0 ppb	Device 2 (1183)	146,4 ppb

The outcome of this are the following averaging effects:

Device 1 (1177): 2,4 %

Device 2 (1183): 1,1 %

## 7.5 Findings

The performance criteria of EN 14212 have been fulfilled.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values are given in Table 24.

Table 24: Measured values of averaging test

Measurement (const)	Device 1 (1177) [ppb]	Device 2 (1183) [ppb]
Measurement 1	298,3	296,1
Measurement 2	298,3	296,0
Measurement 3	297,9	295,7
Measurement 4	298,5	296,2
<b>Average C<sub>const</sub></b>	<b>298,2</b>	<b>296,0</b>
<b>Measurement (var)</b>		
conz. t <sub>zero</sub>	196,4	185,3
conz. t <sub>SO<sub>2</sub></sub>	122,4	133,1
conz. t <sub>zero</sub>	159,9	153,0
conz. t <sub>SO<sub>2</sub></sub>	117,4	126,9
conz. t <sub>zero</sub>	166,3	158,8
conz. t <sub>SO<sub>2</sub></sub>	113,9	124,1
conz. t <sub>zero</sub>	168,9	161,1
conz. t <sub>SO<sub>2</sub></sub>	119,5	128,7
<b>Average C<sub>var</sub></b>	<b>145,6</b>	<b>146,4</b>
<b>Averaging effect X<sub>av</sub> [%]</b>		
permitted averaging effect	7%	7%
Status	fulfilled	fulfilled

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### 7.1 8.4.13 Difference sample/calibration port

*Difference between sample/calibration port has to constitute  $\leq 1,0$  %*

### 7.2 General requirement

If the analyzer has different ports for feeding sample gas and calibration gas the difference in response of the analyzer to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyzer with a test gas with a concentration of 70 % to 80 % of the maximum of the certification range through the sample port. The test shall consist of one independent followed by two individual measurements. After a period of at least 4 response times the test shall be repeated using the calibration port. The difference shall be calculated according to:

$$D_{SC} = \frac{x_s - x_c}{c_t} \times 100$$

Where:

$D_{SC}$  is the difference sample/calibration port (%);

$x_s$  is the average of the measured concentrations using the sample port (nmol/mol);

$x_c$  is the average of the measured concentrations using the calibration port (nmol/mol);

$c_t$  is the concentration of the test gas (nmol/mol).

$D_{SC}$  shall comply with the performance criterion.

### 7.3 Performance of test

The analyzers were not equipped with different sample/calibration ports. Just one sample inlet was available.

### 7.4 Evaluation

Here not applicable. For the calculation of total uncertainty the factor  $D_{SC} = 0$  has been taken.

### 7.5 Findings

Here not applicable

Minimum requirement fulfilled? Not applicable

## 7.6 Presentation of test results

As shown in Figure 13 no different gas inlets were available on the tested devices.

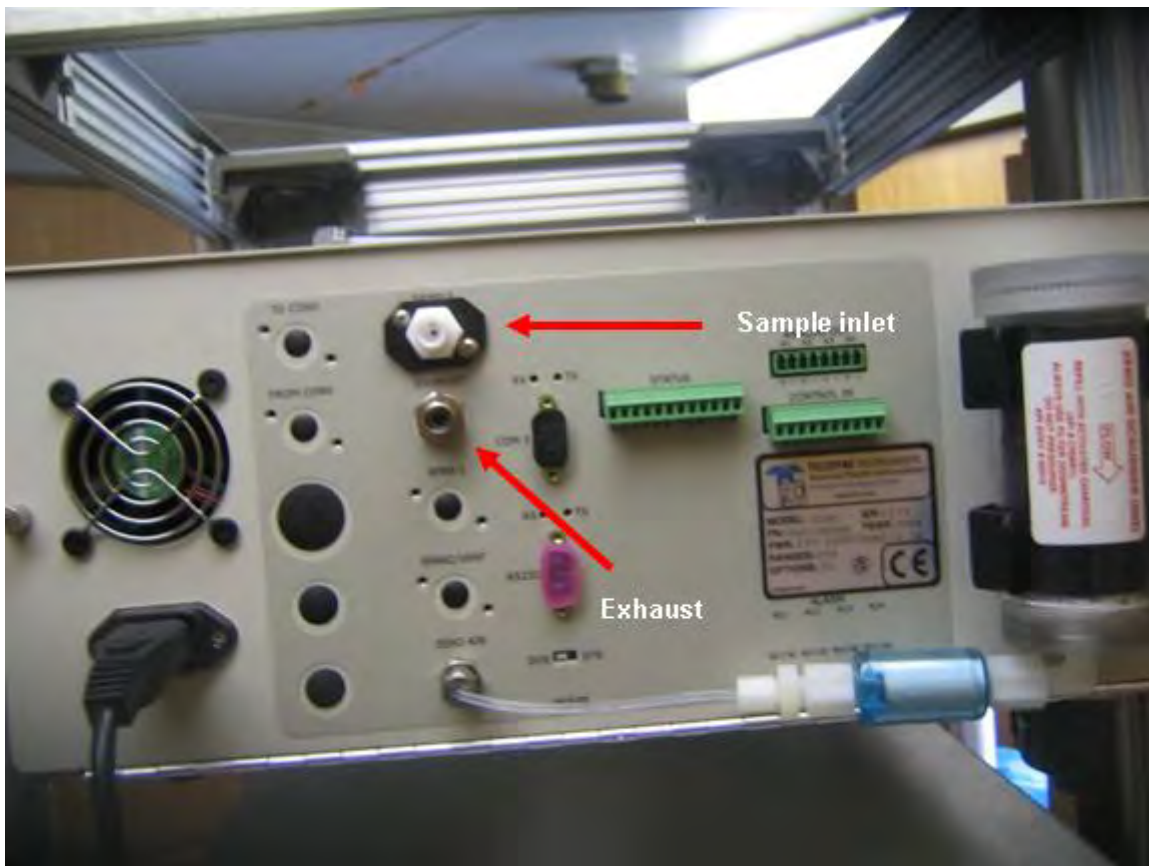


Figure 13: Backside of M100E analyzer

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## 7.1 8.5 Determination of the performance characteristics during the field test

### 8.5.1 Overview

The determination of the performance characteristics in the field as a part of the type approval test shall be performed by a designated body. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this document.

In the field test during a period of three months 2 analyzers are tested for availability (period of unattended operation), reproducibility in the field and long-term drift. The analyzers are run in parallel at one and the same sampling point at a selected monitoring station with specific ambient air conditions. Operational requirements are given for the correct determination of the long-term drift and the reproducibility under field conditions.

### 8.5.2 Selection of a monitoring station for the field test

The selection of a monitoring station is based on the following criteria:

Location:

- periurban or rural station

Monitoring station facilities:

- sufficient capacity of the sampling manifold;
- enough room to place two analyzers with calibration gases and/or calibration facilities;
- surrounding temperature control for analyzers, climate controlled at 20°C ± 4°C with temperature registration;
- stable electrical voltage.

Other items that could be considered:

- presence of telemetry/telephone facilities for remote surveillance of the functioning of the equipment;
- accessibility.

## 7.2 General requirements

### 8.5.3 Operational requirements

After installation of the analyzers at the monitoring station the proper functioning of the analyzers shall be tested. This comprises (among other things) the proper connections to the sampling manifold, sample gas flows, correct temperatures of e.g. reaction chambers, response to zero and span gases, actual converter efficiency, data transmission and other items, which shall be judged necessary by the designated body.

After verification of the proper functioning, the analyzers shall be adjusted at zero and calibrated at a value of about 80 % of the maximum of the certification range.

During the three-month period, the maintenance requirements by the manufacturer of the analyzer shall be followed.

Measurements with zero and span gases shall be performed every two weeks. The concentration  $c_t$  of the span gas shall be around 90 % of the maximum of the certification range. One independent followed by 4 individual measurements shall be performed both at zero and at concentration  $c_t$ . The measurement results shall be recorded.

To exclude the effect of contamination of the filter when determining the drift of the analyzer the zero and span gases shall be fed to the analyzer without passing through the filter.

To avoid the possibility that the filter loading affects the results of the intercomparison of the two analyzers and to ensure that the filter loading will not compromise the quality of the air pollution data collected, the filter shall be changed just before each bi-weekly calibration. Filters, which had been preconditioned in the laboratory using SO<sub>2</sub> gas mixtures, shall be used.

During the three-month period, no zero and span adjustments shall be made to the analyzer, as this will influence the determination of the long-term drift. The measurement data from the analyzer shall only be corrected in a mathematical way assuming a linear drift since the last zero and span check.

If an auto rescaling function or self-correction function is included and considered "normal operational condition", it shall be enabled during the field tests. The magnitude of any self correction shall be available to the test laboratory. The magnitude of the auto zero and the auto span drift corrections over the period of unattended operation (long-term drift) both have the same restrictions as laid down in the performance characteristics.

### **7.3 Performance of test**

Here not required.

### **7.4 Evaluation**

Here not required.

### **7.5 Findings**

The general specifications could be fulfilled.

Minimum requirements fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

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## 7.1 8.5.4 Long-term drift

*Long-term drift at zero  $\leq 5,0$  nmol/mol (equal to 5 ppb)*

*Long-term drift at span  $\leq 5$  % of maximum of certification range (equal to 18,8 ppb at a range from 0 to 376 ppb)*

## 7.2 General requirement

After each bi-weekly calibration the drift of the analyzers under test shall be calculated at zero and at span following the procedures as given underneath. If the drift compared to the initial calibration exceeds one of the performance criteria for drift at zero or span level, the "period of unattended operation" equals the number of weeks till the observation of the infringement, minus two weeks. For further (uncertainty) calculations the values for "long term drift" are the values for zero and span drift over the period of unattended operation.

At the beginning of the drift period five individual measurements are recorded (after waiting the time equivalent to one independent measurement just after the calibration) at zero and at span level.

The long-term drift is calculated as follows:

$$D_{L,Z} = (C_{Z,2} - C_{Z,1})$$

Where:

$D_{L,Z}$  is the drift at zero (nmol/mol);

$C_{Z,1}$  is the average concentration of the measurements at zero at the beginning of the drift period (just after the initial calibration) (nmol/mol);

$C_{Z,2}$  is the average concentration of the measurements at zero at the end of the drift period (nmol/mol) .

$D_{L,Z}$  shall comply with the performance criteria.

$$D_{L,S} = \frac{(C_{S,2} - C_{S,1}) - D_{L,Z}}{C_{S,1}} \times 100$$

Where:

$D_{L,S}$  is the drift at span concentration  $c_t$  (nmol/mol);

$C_{S,1}$  is the average concentration of the measurements at span level at the beginning of the drift period (just after the initial calibration) (nmol/mol);

$C_{S,2}$  is the average concentration of the measurements at span level at the end of the drift period (nmol/mol).

$D_{L,S}$  shall comply with the performance criteria.

### 7.3 Performance of test

The test has been enforced regarding the specifications of EN 14212. During the field test, test gas was given through the analyzers every 2 weeks. For the determination of long term drift the values of every biweekly measurements have been used. Table 25 and Table 26 show the results of the bi-weekly measurements.

### 7.4 Evaluation

Table 25: Results of the long term drift on zero

	Device 1 (1177) [ppb]	Device 2 (1183) [ppb]
C <sub>Z,1</sub> 13.02.2007	-0,01	0
C <sub>Z,2</sub> 23.02.2007	0,52	0,52
<b>D<sub>L,Z</sub> 23.02.2007</b>	<b>0,53</b>	<b>0,52</b>
C <sub>Z,2</sub> 09.03.2007	0,3	0,6
<b>D<sub>L,Z</sub> 09.03.2007</b>	<b>0,31</b>	<b>0,6</b>
C <sub>Z,2</sub> 23.03.2007	0,52	0,07
<b>D<sub>L,Z</sub> 23.03.2007</b>	<b>0,53</b>	<b>0,07</b>
C <sub>Z,2</sub> 05.04.2007	1,05	0,6
<b>D<sub>L,Z</sub> 05.04.2007</b>	<b>1,06</b>	<b>0,6</b>
C <sub>Z,2</sub> 19.04.2007	0,68	1,35
<b>D<sub>L,Z</sub> 19.04.2007</b>	<b>0,69</b>	<b>1,35</b>
C <sub>Z,2</sub> 04.05.2007	0,9	0,97
<b>D<sub>L,Z</sub> 04.05.2007</b>	<b>0,91</b>	<b>0,97</b>
C <sub>Z,2</sub> 14.05.2007	0,977	0,37
<b>D<sub>L,Z</sub> 14.05.2007</b>	<b>0,987</b>	<b>0,37</b>



Table 26: Results of the long term drift at span

		Device 1 (1177) [ppb]	Device 2 (1183) [ppb]
C <sub>S,1</sub>	13.02.2007	300,9	302
C <sub>S,2</sub>	23.02.2007	303,4	302,7
<b>D<sub>L,S</sub></b>	<b>23.02.2007</b>	<b>0,66%</b>	<b>0,06%</b>
C <sub>S,2</sub>	09.03.2007	305,7	302,8
<b>D<sub>L,S</sub></b>	<b>09.03.2007</b>	<b>1,50%</b>	<b>0,07%</b>
C <sub>S,2</sub>	23.03.2007	297,5	304,4
<b>D<sub>L,S</sub></b>	<b>23.03.2007</b>	<b>-1,30%</b>	<b>0,77%</b>
C <sub>S,2</sub>	05.04.2007	304,6	307,3
<b>D<sub>L,S</sub></b>	<b>05.04.2007</b>	<b>0,88%</b>	<b>1,56%</b>
C <sub>S,2</sub>	19.04.2007	305,7	305,8
<b>D<sub>L,S</sub></b>	<b>19.04.2007</b>	<b>1,37%</b>	<b>0,81%</b>
C <sub>S,2</sub>	04.05.2007	301,1	302,4
<b>D<sub>L,S</sub></b>	<b>04.05.2007</b>	<b>-0,23%</b>	<b>-0,19%</b>
C <sub>S,2</sub>	14.05.2007	304,7	306,4
<b>D<sub>L,S</sub></b>	<b>14.05.2007</b>	<b>0,94%</b>	<b>1,33%</b>

## 7.5 Findings

For device 1 (1177) a maximum long term drift of 1,06 ppb at zero and maximum 1,49 % of range at span could be determined.

For device 2 (1183) a maximum long term drift of 1,35 ppb at zero and maximum 1,56 % of range at span could be determined.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

The measured values of the long term drift are stated in Table 27.

Table 27: Measured values of the determination of the long term drift

Datum	Time	Device 1 (1177)	Device 2 (1183)	Time	Device 1 (1177)	Device 2 (1183)
	Zero Point			Span Point		
	[hh:mm]	[ppb]	[ppb]	[hh:mm]	[ppb]	[ppb]
13.02.2007	13:23	-0,01	0	13:37	300,5	301,8
13.02.2007	13:25	-0,01	0	13:39	300,2	301,4
13.02.2007	13:27	0	0	13:41	300,8	302,0
13.02.2007	13:29	0	0,01	13:43	301,4	302,1
13.02.2007	13:31	-0,01	0,01	13:45	301,6	302,5
<b>Mittelwert</b>		<b>-0,01</b>	<b>0,00</b>		<b>300,9</b>	<b>302,0</b>
23.02.2007	13:20	0,52	0,52	13:50	303,4	302,7
09.03.2007	13:45	0,3	0,6	14:15	305,7	302,8
23.03.2007	13:45	0,52	0,07	14:15	297,5	304,4
05.04.2007	13:25	1,05	0,6	13:55	304,6	307,3
19.04.2007	13:45	0,68	1,35	14:15	305,7	305,8
04.05.2007	13:25	0,9	0,97	13:55	301,1	302,4
14.05.2007	12:20	0,977	0,37	12:50	304,7	306,4

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### 7.1 8.5.5 Reproducibility under field conditions

*Reproducibility standard deviation under field conditions should be 5 % of the average over a three month period.*

### 7.2 General requirement

The reproducibility standard deviation under field conditions is calculated from the measured hourly averaged data during the three months period.

The difference  $d_f$  for each  $i$ -th parallel measurement is calculated from::

$$d_{f,i} = (x_{1,f})_i - (x_{2,f})_i$$

Where:

$d_{f,i}$  is the  $i^{\text{th}}$  difference in a parallel measurement (nmol/mol);

$(x_{1,f})_i$  is the  $i$ th measurement result of analyzer 1 (nmol/mol);

$(x_{2,f})_i$  is the  $i$ th measurement result of analyzer 2 at the same time as the measurement of analyzer 1 (nmol/mol)

The reproducibility (under field conditions) standard deviation ( $s_{r,f}$ ) is calculated according to:

$$s_{r,f} = \frac{\left( \sqrt{\frac{\sum_{i=1}^n d_{f,i}^2}{2n}} \right)}{av} \times 100$$

Where:

$s_{r,f}$  is the reproducibility standard deviation under field conditions (%);

$n$  is the number of parallel measurements;

$av$  is the average value during the field test ( $\mu\text{mol/mol}$ );

$d_{f,i}$  is the  $i^{\text{th}}$  difference in a parallel measurement ( $\mu\text{mol/mol}$ ).

The reproducibility standard deviation under field conditions,  $s_r$ , shall comply with the performance criterion.

### 7.3 Performance of test

The standard deviation during field test has been determined from the hourly averaged values during field test period.

## 7.4 Evaluation

Table 28: Determination of standard deviation during field test

Standard deviation during field test			
Number of parallel measurements	n	=	2171
Average value during the field test	av	=	4,26 ppb
Standard deviation of parallel measurements	sd	=	0,206
<b>Reproducibility standard deviation (%)</b>	<b>S<sub>r,f</sub></b>	=	<b>4,80 %</b>

The standard deviation during field test is with 4,80 % of the three month average within the allowed limits.

## 7.5 Findings

The performance criteria of EN 14212 have been fulfilled.

Minimum requirement fulfilled? yes

## 7.6 Presentation of test results

Here not required.

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### **7.1 8.5.6 Period of unattended operation**

*The period of unattended operation shall be not less than 2 weeks.*

### **7.2 General requirement**

The period of unattended operation is the time period within which the drift is within the performance criterion for long-term drift. If the manufacturer specifies a shorter period for maintenance, than this will be taken as the period of unattended operation. If one of the analyzers malfunctions during the field test, than the field test shall be restarted to show whether the malfunction was coincidental or bad design.

### **7.3 Performance of testing**

The performance criteria's of long term drift (chapter 8.5.4) have been fulfilled during the three month field test. But he sample filters behind the gas inlet have been changed monthly.

### **7.4 Evaluation**

A maintenance interval of 4 weeks was determined because of the data of the long term drift investigation (Table 25 and Table 26) and the monthly maintenance work.

### **7.5 Findings**

The determined maintenance interval is at least 4 weeks.

Minimum requirement fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

## 7.1 8.5.7 period of availability of the analyzer

*Period of availability of the analyzer > 90 %.*

## 7.2 General requirement

The correct operation of the analyzers shall be checked at least every 14 days. It is recommended to perform this check every day during the first 14 days. These checks consists of plausibility checks on the measured values, as well as when available status signals and other relevant parameters. Time, duration and nature of any malfunctioning shall be logged.

The total time period with useable measuring data is the period during the field test during which valid measuring data of the ambient air concentrations are obtained. In this time period the time needed for calibrations, conditioning of sample lines and filters and maintenance shall not be included.

The availability of the analyzer is calculated as:

$$A_a = \frac{t_u}{t_t} * 100$$

Where:

$A_a$  is the availability of the analyzer;

$t_u$  is the total time period with validated measuring data;

$t_t$  is the time period of the field test minus the time for calibration, conditioning and maintenance.

$t_u$  and  $t_t$  shall be expressed in the same units.

The availability of each analyzer shall comply the performance criterion in.

## 7.3 Performance of testing

The total operating time is calculated from the start and final time of field test. The other periods of time are taken from the documentation of the test.

## 7.4 Evaluation

The periods of time for the determination of the availability for both analyzers are stated in Table 29.

Table 29: Availability of M100E

			Device 1 (1177)	Device 2 (1183)
Total running time	$t_t$	h	2171	2171
Calibration/maintenance	--	h	31	31
Operating time	$t_u$	h	2140	2140
Availability	$A_a$	%	98,6 %	98,6 %

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The calibrating times result from the daily test gas tasks for the determination of the drift behavior and the maintenance interval. There have been no device caused outage times during the field test. The maintenance time results from the time needed for the replacement of the Teflon filter.

### **7.5 Findings**

The Availability is with 98,6 % higher than the required 90 %.

Minimum requirement fulfilled? yes

### **7.6 Presentation of test results**

Here not required.

## **Appendix G (normative) Type approval after DIN EN 14212**

*The type approval of the analyzer consists of the following steps:*

- 1) The value of each individual performance characteristic tested in the laboratory shall fulfill the criterion stated in table 1 (see 8.2 in DIN EN 14212).*
- 2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests fulfils the criterion as stated in the Council Directive 99/30/EC. This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in annex G of the DIN EN 14212.*
- 3) The value of each of the individual performance characteristics tested in the field shall fulfill the criterion stated in table 1 (see 8.2 of the DIN EN 14212).*
- 4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests fulfils the criterion as stated in the Council Directive 99/30/EC. This criterion is the maximum uncertainty of hourly values of continuous measurements at the hourly limit value. The relevant specific performance characteristics and the calculation procedure are given in annex G of the DIN EN 14212.*

### **7.2 General requirements**

Calculation according to annex G of the DIN EN 14212.

### **7.3 Performance of the test**

At the end of the testing all elementary uncertainties have been calculated from of the test data.

### **7.4 Evaluation**

- to 1) The value of each single tested performance characteristic in the lab fulfils the criterion of the DIN EN 14212.
- to 2) The expanded uncertainty, calculated of the specific performance characteristics obtained in the laboratory tests, fulfils the performance criterion.
- to 3) The value of each single tested performance characteristic in the field fulfils the criterion of the DIN EN 14212.
- to 4) The expanded uncertainty, calculated of the specific performance characteristics obtained in the laboratory and the field tests, fulfils the performance criterion.



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## **7.5 Assessment**

The performance criteria of EN 14212 have been fulfilled.

Minimum requirement fulfilled? yes

## **7.6 Presentation of test results**

The results of point 1 and 3 are summarized Table 30.

The results of point 2 are stated in Table 31 and Table 33.

The results of point 4 are stated in Table 32 and Table 34.

Table 30: Summary of test results

Performance characteristic	Performance criterion	Test result	Fulfilled	Page
8.4.5 Repeatability standard deviation at zero	$\leq 1,0$ nmol/mol	S <sub>r</sub> Device 1177: 0,3 ppb S <sub>r</sub> Device 1183: 0,3 ppb	yes	29
8.4.5 Repeatability standard deviation at concentration ct	$\leq 3,0$ nmol/mol	S <sub>r</sub> Device 1177: 0,5 ppb S <sub>r</sub> Device 1183: 0,9 ppb	yes	29
8.4.6 „lack of fit“ (residual from the linear regression function)	Largest residual from the linear regression function $\leq 4$ % of the measured value Residual at zero $\leq 5,0$ nmol/mol	X <sub>i,z</sub> Device 1177: NP 0,3 ppb X <sub>i</sub> Device 1177: RP -0,8 % X <sub>i,z</sub> Device 1183: NP 0,2 ppb X <sub>i</sub> Device 1183: RP 0,9 %	yes	31
8.4.7 Sensitivity coefficient of sample gas pressure	$\leq 2,0$ nmol/mol/kPa	b <sub>gp</sub> Device 1177: 0,02 ppb/kPa b <sub>gp</sub> Device 1183: 0,06 ppb/kPa	yes	37
8.4.8 Sensitivity coefficient of sample gas temperature	$\leq 1,0$ nmol/mol/K	b <sub>gt</sub> Device 1177: -0,013 ppb/K b <sub>gt</sub> Device 1183: 0,013 ppb/K	yes	39
8.4.9 Sensitivity coefficient of surrounding temperature	$\leq 1,0$ nmol/mol/K	b <sub>st</sub> Device 1177: 0,05 ppb/K b <sub>st</sub> Device 1183: 0,03 ppb/K	yes	41
8.4.10 Sensitivity coefficient of electrical voltage	$\leq 0,3$ nmol/mol/V	b <sub>v</sub> Device 1177: NP -0,01 ppb/V b <sub>v</sub> Device 1177: RP 0,00 ppb/V b <sub>v</sub> Device 1183: NP -0,01 ppb/V b <sub>v</sub> Device 1183: RP 0,02 ppb/V	yes	45
8.4.11 Interferents at zero and concentration ct	H <sub>2</sub> O $\leq 10$ nmol/mol H <sub>2</sub> S $\leq 5,0$ nmol/mol NH <sub>3</sub> $\leq 5,0$ nmol/mol NO $\leq 5,0$ nmol/mol NO <sub>2</sub> $\leq 5,0$ nmol/mol m-Xylol $\leq 10,0$ nmol/mol	H <sub>2</sub> O Device 1177: NP -0,4 ppb / RP -1,7 ppb Device 1183: NP -0,1 ppb / RP -1,6 ppb H <sub>2</sub> S Device 1177: NP 0,3 ppb / RP 0,9 ppb Device 1183: NP 0,4 ppb / RP 0,4 ppb NH <sub>3</sub> Device 1177: NP 0,3 ppb / RP 0,1 ppb Device 1183: NP 0,3 ppb / RP 1,1 ppb NO Device 1177: NP 0,5 ppb / RP 3,2 ppb Device 1183: NP 0,4 ppb / RP 2,9 ppb NO <sub>2</sub> Device 1177: NP 0,0 ppb / RP 0,5 ppb Device 1183: NP 0,1 ppb / RP 0,8 ppb m-Xylol Device 1177: NP 0,0 ppb / RP 1,2 ppb Device 1183: NP 0,3 ppb / RP 0,9 ppb	yes	47

Performance characteristic	Performance criterion	Test result	Fulfilled	Page
8.4.12 Averaging effect	≤ 7,0 % of the measured value	X <sub>av</sub> Device 1177: 2,4 % X <sub>av</sub> Device 1183: 1,1 %	yes	50
8.4.13 Difference between sample/calibration port	≤ 1,0 %	D <sub>SC</sub> Device 1177: ---- D <sub>SC</sub> Device 1183: ----	Not applicable	53
8.4.3 Response time (rise)	≤ 180 s	t <sub>r</sub> Device 1177: max. 78 s t <sub>r</sub> Device 1183: max. 80 s	yes	22
8.4.3 Response time (fall)	≤ 180 s	t <sub>f</sub> Device 1177: max. 80 s t <sub>f</sub> Device 1183: max. 80 s	yes	22
8.4.3 Difference between rise and fall time	≤ 10 % relative difference or 10 s whatever is the greatest	t <sub>d</sub> Device 1177: 2,0 % or 3 s t <sub>d</sub> Device 1183: 2,3 % or 5 s	yes	22
8.5.6 Period of unattended operation	3 month or less if manufacturer indicates a shorter period, but not less than 2 weeks	Device 1177: 4 weeks Device 1183: 4 weeks	yes	63
8.5.7 Availability of the analyzer	> 90 %	A <sub>a</sub> Device 1177: 98,6 % A <sub>a</sub> Device 1183: 98,6 %	yes	64
8.5.5 Reproducibility standard deviation under field conditions	≤ 5,0 % of the average of a three month period	S <sub>r,f</sub> Device 1177: 4,80 % S <sub>r,f</sub> Device 1183: 4,80 %	yes	61
8.5.4 Long-term drift at zero	≤ 5,0 nmol/mol	D <sub>l,z</sub> Device 1177: 1,06 ppb D <sub>l,z</sub> Device 1183: 1,35 ppb	yes	57
8.5.4 Long-term drift at span level	≤ 5,0 % of the average of a three month period	D <sub>l,s</sub> Device 1177: max. 1,49 % D <sub>l,s</sub> Device 1183: max. 1,56 %	yes	57
8.4.4 Short-term drift at zero	≤ 2,0 nmol/mol over 12 h	D <sub>s,z</sub> Device 1177: 0,0 ppb D <sub>s,z</sub> Device 1183: 0,4 ppb	yes	26
8.4.4 Short-term drift at span level	≤ 6,0 nmol/mol over 12 h	D <sub>s,s</sub> Device 1177: -1,4 ppb D <sub>s,s</sub> Device 1183: -1,4 ppb	yes	26

Table 31: Expanded uncertainty obtained in the laboratory test for device 1177

Instrument:		Teledyne		Serial-No.:		SN 1 (1177)	
Component:		SO <sub>2</sub>		1h-limit value:		132 nmol/mol	
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,300	u <sub>r,z</sub>	0,04	0,0020	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	0,500	u <sub>r,v</sub>	0,08	0,0058	
3	"lack of fit"	≤ 4,0%	-0,800	u <sub>l,v</sub>	-0,61	0,3717	
4	Sensitivity coefficient of sample gas pressure	≤ 3,0 nmol/mol/kPa	0,020	u <sub>sp</sub>	0,53	0,2846	
5	Sensitivity coefficient of sample gas temperature	≤ 1,0 nmol/mol/K	-0,013	u <sub>st</sub>	-0,10	0,0105	
6	Sensitivity coefficient of surrounding temperature	≤ 1,0 nmol/mol/K	0,050	u <sub>st</sub>	0,39	0,1554	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	-0,010	u <sub>v</sub>	-0,11	0,0117	
8a	H <sub>2</sub> O with concentration 21 nmol/mol	≤ 10 nmol/mol	-1,935	u <sub>H<sub>2</sub>O</sub>	1,31	1,7066	
8b	H <sub>2</sub> S with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,909	u <sub>int,pos</sub>	3,45	11,8950	
8c	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,097				
8d	NO with concentration 500 nmol/mol	≤ 5,0 nmol/mol	3,242	or	3,45	11,8950	
8e	NO <sub>2</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,508				
8f	m-Xylol with concentration 1 µmol/mol	≤ 10 nmol/mol	1,218	u <sub>int,neg</sub>			
9	Averaging effect	≤ 7,0%	2,400	u <sub>av</sub>	1,83	3,3454	
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>pac</sub>	0,00	0,0000	
23	Uncertainty calibration gas	≤ 3,0%	1,000	ucg	0,66	0,4356	
combined standard uncertainty				u <sub>c</sub>		4,2690	nmol/mol
expanded uncertainty				U <sub>c</sub>		8,5380	nmol/mol
expanded uncertainty actual				U <sub>c,rel</sub>		6,47	%
expanded uncertainty required				U <sub>req,rel</sub>		15	%

Table 32: Expanded uncertainty obtained in the laboratory and field test for device 1177

Instrument:		Teledyne		Serial-No.:		SN 1 (1177)	
Component:		SO <sub>2</sub>		1h-limit value:		132 nmol/mol	
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty	
1	Repeatability at zero	≤ 1,0 nmol/mol	0,300	u <sub>r,z</sub>	0,04	0,0020	
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	0,500	u <sub>r,v</sub>	not respected because u <sub>r,v</sub> = 0,07 < u <sub>r,f</sub>	-	
3	"lack of fit"	≤ 4,0%	-0,800	u <sub>l,v</sub>	-0,61	0,3717	
4	Sensitivity coefficient of sample gas pressure	≤ 3,0 nmol/mol/kPa	0,020	u <sub>sp</sub>	0,53	0,2846	
5	Sensitivity coefficient of sample gas temperature	≤ 1,0 nmol/mol/K	-0,013	u <sub>st</sub>	-0,10	0,0105	
6	Sensitivity coefficient of surrounding temperature	≤ 1,0 nmol/mol/K	0,050	u <sub>st</sub>	0,39	0,1554	
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	-0,010	u <sub>v</sub>	-0,11	0,0117	
8a	H <sub>2</sub> O with concentration 21 nmol/mol	≤ 10 nmol/mol	-1,935	u <sub>H<sub>2</sub>O</sub>	1,31	1,7066	
8b	H <sub>2</sub> S with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,909	u <sub>int,pos</sub>	3,45	11,8950	
8c	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,097				
8d	NO with concentration 500 nmol/mol	≤ 5,0 nmol/mol	3,242	or	3,45	11,8950	
8e	NO <sub>2</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,508				
8f	m-Xylol with concentration 1 µmol/mol	≤ 10 nmol/mol	1,218	u <sub>int,neg</sub>			
9	Averaging effect	≤ 7,0%	2,400	u <sub>av</sub>	1,83	3,3454	
10	Reproducibility under field conditions	≤ 5,0% of the average of 3 Mon.	4,800	u <sub>r,f</sub>	6,34	40,1449	
11	Long term drift at zero level	≤ 5,0 nmol/mol	1,060	u <sub>d,z</sub>	0,61	0,3745	
12	Long term drift at span level	≤ 5,0% of max. of certification range	1,490	u <sub>d,v</sub>	1,14	1,2894	
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>pac</sub>	0,00	0,0000	
23	Uncertainty calibration gas	≤ 3,0%	1,000	ucg	0,66	0,4356	
combined standard uncertainty				u <sub>c</sub>		7,7477	nmol/mol
expanded uncertainty				U <sub>c</sub>		15,4955	nmol/mol
expanded uncertainty actual				U <sub>c,rel</sub>		11,74	%
expanded uncertainty required				U <sub>req,rel</sub>		15	%

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Table 33: Expanded uncertainty obtained in the laboratory test for device 1183

Instrument:		Teledyne		Serial-No.:		SN 2 (1183)		
Component:		SO <sub>2</sub>		1h-limit value:		132 nmol/mol		
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty		
1	Repeatability at zero	≤ 1,0 nmol/mol	0,500	u <sub>r,z</sub>	0,07	0,0056		
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	0,900	u <sub>r,v</sub>	0,14	0,0185		
3	"lack of fit"	≤ 4,0%	0,900	u <sub>r,v</sub>	0,69	0,4704		
4	Sensitivity coefficient of sample gas pressure	≤ 3,0 nmol/mol/kPa	0,060	u <sub>sp</sub>	1,60	2,5613		
5	Sensitivity coefficient of sample gas temperature	≤ 1,0 nmol/mol/K	0,013	u <sub>st</sub>	0,10	0,0105		
6	Sensitivity coefficient of surrounding temperature	≤ 1,0 nmol/mol/K	0,030	u <sub>st</sub>	0,24	0,0559		
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,020	u <sub>v</sub>	0,22	0,0467		
8a	H <sub>2</sub> O with concentration 21 nmol/mol	≤ 10 nmol/mol	-1,826	u <sub>H<sub>2</sub>O</sub>	1,23	1,5196		
8b	H <sub>2</sub> S with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,400	u <sub>int,pos</sub> or u <sub>int,neg</sub>	3,56	12,6928		
8c	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	1,112					
8d	NO with concentration 500 nmol/mol	≤ 5,0 nmol/mol	2,938					
8e	NO <sub>2</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,811					
8f	m-Xylol with concentration 1 µmol/mol	≤ 10 nmol/mol	0,909					
9	Averaging effect	≤ 7,0%	1,100					u <sub>av</sub>
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>psc</sub>	0,00	0,0000		
23	Uncertainty calibration gas	≤ 3,0%	1,000	0	0,66	0,4356		
				combined standard uncertainty		u <sub>c</sub>	4,3035	nmol/mol
				expanded uncertainty		U <sub>c</sub>	8,6069	nmol/mol
				expanded uncertainty actual		U <sub>c,rel</sub>	6,52	%
				expanded uncertainty required		U <sub>req,rel</sub>	15	%

Table 34: Expanded uncertainty obtained in the laboratory and field test for device 1183

Messgerät:		Teledyne		Seriennummer:		SN 2 (1183)		
Messkomponente:		SO <sub>2</sub>		1h-Grenzwert:		132 nmol/mol		
No.	Performance characteristic	Performance criteria	Result	partial uncertainty		Square of uncertainty		
1	Repeatability at zero	≤ 1,0 nmol/mol	0,500	u <sub>r,z</sub>	0,07	0,0056		
2	Repeatability at concentration ct	≤ 3,0 nmol/mol	0,900	u <sub>r,v</sub>	not respected because $u_{r,v} = 0,13 < u_{r,f}$	-		
3	"lack of fit"	≤ 4,0%	0,900	u <sub>r,v</sub>	0,69	0,4704		
4	Sensitivity coefficient of sample gas pressure	≤ 3,0 nmol/mol/kPa	0,060	u <sub>sp</sub>	1,60	2,5613		
5	Sensitivity coefficient of sample gas temperature	≤ 1,0 nmol/mol/K	0,013	u <sub>st</sub>	0,10	0,0105		
6	Sensitivity coefficient of surrounding temperature	≤ 1,0 nmol/mol/K	0,030	u <sub>st</sub>	0,24	0,0559		
7	Sensitivity coefficient of electrical voltage	≤ 0,30 nmol/mol/V	0,020	u <sub>v</sub>	0,22	0,0467		
8a	H <sub>2</sub> O with concentration 21 nmol/mol	≤ 10 nmol/mol	-1,826	u <sub>H<sub>2</sub>O</sub>	1,23	1,5196		
8b	H <sub>2</sub> S with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,400	u <sub>int,pos</sub> or u <sub>int,neg</sub>	3,56	12,6928		
8c	NH <sub>3</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	1,112					
8d	NO with concentration 500 nmol/mol	≤ 5,0 nmol/mol	2,938					
8e	NO <sub>2</sub> with concentration 200 nmol/mol	≤ 5,0 nmol/mol	0,811					
8f	m-Xylol with concentration 1 µmol/mol	≤ 10 nmol/mol	0,909					
9	Averaging effect	≤ 7,0%	1,100					u <sub>av</sub>
10	Reproducibility under field conditions	≤ 5,0% of the average of 3 Mon.	4,800	u <sub>r,f</sub>	6,34	40,1449		
11	Long term drift at zero level	≤ 5,0 nmol/mol	1,350	u <sub>dr,z</sub>	0,78	0,6075		
12	Long term drift at span level	≤ 5,0% of max. of certification range	1,560	u <sub>dr,v</sub>	1,19	1,4134		
18	Difference sample/calibration port	≤ 1,0%	0,000	u <sub>psc</sub>	0,00	0,0000		
23	Uncertainty calibration gas	≤ 3,0%	1,000	0	0,66	0,4356		
				combined standard uncertainty		u <sub>c</sub>	7,7889	nmol/mol
				expanded uncertainty		U <sub>c</sub>	15,5778	nmol/mol
				expanded uncertainty actual		U <sub>c,rel</sub>	11,80	%
				expanded uncertainty required		U <sub>req,rel</sub>	15	%

## 7. Recommendations for the use in practice

### 7.1 Work in the maintenance interval

In addition to the usual calibrating work it is important to frequently check the state of the inlet contained Teflon filters in front of the analyzer. The duration of the replacement interval of the filters which are to prevent the pollution of the devices through the sucked ambient air depends on the dust load at the location of installation. The alternating interval is committed to one month.

By the way, the statements of the manufacturer are to be considered.

Department of Environmental protection



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Dipl.-Ing. Martin Schneider



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Dipl.-Ing. Karsten Pletscher

Cologne, 22.06.2007  
936/21205926/B1

Translation of the report on the suitability test of the ambient air measuring system M100E of the company Teledyne Advanced Pollution Instrumentation for the measurement of SO<sub>2</sub>,  
Report-No.: 936/21205926/B1

## 8 Literature

- VDI 4202 Blatt 1: Mindestanforderungen an automatische Immissionsmeseinrichtungen bei der Eignungsprüfung; Punktmessverfahren für gas- und partikelförmige Luftverunreinigungen, vom Juni 2002
- VDI 4203 Blatt 3: Prüfpläne für automatische Messeinrichtungen; Prüfprozeduren für Messeinrichtungen zur punktförmigen Messung von - und partikelförmigen Immissionen, vom August 2004
- DIN EN 14211 Luftqualität – Messverfahren zur Bestimmung der Konzentration von Stickstoffdioxid und Stickstoffmonoxid mit Chemolumineszenz, Juni 2005
- VDI 2551 Blatt 3: Messen der Schwefeldioxid Konzentration – Photometrisches Verfahren (TCM-Verfahren), 1996
- Richtlinie 96/62/EG des Rates vom 27. September 1996 über die Beurteilung und die Kontrolle der Luftqualität ABl. L 296, S. 55

## 9 Appendix

Appendix 1: Manual

Translation of the report on the suitability test of the ambient air measuring system M100E of the company Teledyne Advanced Pollution Instrumentation for the measurement of SO<sub>2</sub>, Berichts-Nr.: 936/21205926/B1

## **Appendix 1:**

### **Manual**



**TÜV RHEINLAND  
ENERGIE UND UMWELT GMBH**



# Addendum

Addendum II to the type approval report of the measuring system M100E (respective T100) for sulfur dioxide from Teledyne Advanced Pollution Instrumentation to the TÜV test report 936/21205926/B from 22.06.2007

Test report No.: 936/21221556/A  
Cologne, March 16, 2013



[luft@de.tuv.com](mailto:luft@de.tuv.com)

**The department of Environmental Protection of TÜV Rheinland Energie und Umwelt GmbH**  
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- Determination of air quality and emissions of air pollution and odour substances;
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Combustion chamber measurements;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of stack height and air quality projections for hazardous and odour substances;
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The accreditation is valid up to 22-01-2018. DAkkS-register number: D-PL-11120-02-00.

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**TÜV Rheinland Energie und Umwelt GmbH**  
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## Abstract

The following Addendum II contains an assessment of the measuring system Teledyne API M100E (respectively T100) for the component sulfur dioxide in terms of compliance with the requirements of the European standard EN 14212 in the version of 2012.

The measuring system Teledyne API M200E (respectively T100) were type-approved and announced as follows:

- M100E for SO<sub>2</sub> with announcement of the Federal Environment Agency on 23<sup>rd</sup> of September 2007 (BAnz. page 7925, chapter II number 1.1)

The announcement of the new design of the T-series was performed by notification:

- M100E respectively T100 for SO<sub>2</sub> with announcement of the Federal Environment Agency on 10<sup>th</sup> of January 2011 (BAnz. page 294, chapter IV notification 19 und 20), statement on 29<sup>th</sup> of September 2010

The measuring system M100E respectively T100 for SO<sub>2</sub>, from Teledyne Advanced Pollution Instrumentation meets also the requirements of DIN EN 14212 (version June 2005). Furthermore the manufacturing and quality management of the measuring system M100E and T100 for SO<sub>2</sub> fulfill the requirements of EN 15267. The related announcement was performed by notification:

- M100E and T100 for SO<sub>2</sub> with announcement of the Federal Environmental Agency on 12<sup>th</sup> of February 2013 (BAnz. AT, 05<sup>th</sup> of March 2013 B10, chapter V notification 3) statement on 11<sup>th</sup> of October 2012

Meanwhile the European standard EN 14212 was revised and re-released in the new version in November 2012. As part of the revision minimum performance criteria for type approval test have been revised.

The compliance with the requirements of the European standard EN 14212 (November 2012) for the measuring systems Teledyne API M100E (respectively T100) for the component sulfur dioxide should be analyzed and documented within the following Addendum II. After its publication this Addendum II is an integral part of the TÜV Rheinland test report with the number 936/21205926/B as well as part of the addendum to the report with the reporting number 936/21218734/A and will also be available in the Internet under [www.qal1.de](http://www.qal1.de).

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## 1. Overview of the results of the tests of the measuring system M100E (respectively T100) according to standard EN 14212 (November 2012)

The following table gives an overview of the performance characteristics, performance criteria and test results according to standard DIN EN 14212 (November 2012) (based on test report 936/21205926/B from 22<sup>nd</sup> of June 2007 + Addendum to report with the report number 936/21218734/A of 11<sup>th</sup> of October 2012). In addition the changes between the requirements of the version from 2005 and the current version of 2012 will be pointed out. In the following chapters an explicit statement to these points can be found. Also the uncertainty calculation was updated to the status of the current standard version of 2012.

Performance characteristic	Performance criterion	Test result	complies	Compliance documented in
8.4.5 Repeatability standard deviation at zero	$\leq 1.0$ nmol/mol	S <sub>rz</sub> device 1177: 0.3 ppb S <sub>rz</sub> device 1183: 0.3 ppb	yes	936/21205926/B from 22. July 2007
8.4.5 Repeatability standard deviation at concentration ct	$\leq 3.0$ nmol/mol	S <sub>rc</sub> device 1177: 0.5 ppb S <sub>rc</sub> device 1183: 0.9 ppb	yes	936/21205926/B from 22. July 2007
8.4.6 Lack of fit (residual from the linear regression function)	Largest residual from the linear regression function at concentrations higher than zero $\leq 4$ % of the measured value  Residual at zero $\leq 5.0$ nmol/mol	r <sub>z</sub> device 1177: ZP 0.47 ppb r <sub>max</sub> device 1177: SP -0.4 % r <sub>z</sub> device 1183: ZP -0.28 ppb r <sub>max</sub> device 1183: SP 0.2 %	yes	936/21218734/A from 11. October 2012
8.4.7 Sensitivity coefficient of sample gas pressure	$\leq 2.0$ nmol/mol/kPa	b <sub>gp</sub> device 1177: 0.02 ppb/kPa b <sub>gp</sub> device 1183: 0.06 ppb/kPa	yes	Yes. refer to point 2
8.4.8 Sensitivity coefficient of sample gas temperature	$\leq 1.0$ nmol/mol/K	b <sub>gt</sub> device 1177: -0.013 ppb/K b <sub>gt</sub> device 1183: 0.013 ppb/K	yes	936/21205926/B from 22. July 2007
8.4.9 Sensitivity coefficient of surrounding temperature	$\leq 1.0$ nmol/mol/K	b <sub>st</sub> device 1177: 0.05 ppb/K b <sub>st</sub> device 1183: 0.03 ppb/K	yes	936/21205926/B from 22. July 2007
8.4.10 Sensitivity coefficient of electrical voltage	$\leq 0.3$ nmol/mol/V	b <sub>v</sub> device 1177: ZP -0.01 ppb/V b <sub>v</sub> device 1177: SP 0.00 ppb/V b <sub>v</sub> device 1183: ZP -0.01 ppb/V b <sub>v</sub> device device 1183: SP 0.02 ppb/V	yes	936/21205926/B from 22. July 2007
8.4.11 Interferents at zero and at concentration ct	H <sub>2</sub> O $\leq 10$ nmol/mol H <sub>2</sub> S $\leq 5$ nmol/mol NH <sub>3</sub> $\leq 5$ nmol/mol NO $\leq 5$ nmol/mol NO <sub>2</sub> $\leq 5$ nmol/mol m-Xylene $\leq 10$ nmol/mol	H <sub>2</sub> O device 1177: ZP -0.4 ppb / SP -1.7 ppb device 1183: ZP -0.1 ppb / SP -1.6 ppb H <sub>2</sub> S device 1177: ZP 0.3 ppb / SP 0.9 ppb device 1183: ZP 0.4 ppb / SP 0.4 ppb	yes	936/21205926/B from 22. July 2007

Addendum II to the type approval report of the measuring system  
 M100E (respective T100) for sulfur dioxide from Teledyne Advanced  
 Pollution Instrumentation, Report-No.: 936/21221556/A

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Performance characteristic	Performance criterion	Test result	complies	Compliance documented in
		NH <sub>3</sub> device 1177: ZP 0.3 ppb / SP 0.1 ppb device 1183: ZP 0.3 ppb / SP 1.1 ppb NO device 1177: ZP 0.5 ppb / SP 3.2 ppb device 1183: ZP 0.4 ppb / SP 2.9 ppb NO <sub>2</sub> device 1177: ZP 0.0 ppb / SP 0.5 ppb device 1183: ZP 0.1 ppb / SP 0.8 ppb m-Xylene device 1177: ZP 0.0 ppb / SP 1.2 ppb device 1183: ZP 0.3 ppb / SP 0.9 ppb		
8.4.12 Averaging effect	≤ 7.0 % of the value	E <sub>av</sub> device 1177: 2.4 % E <sub>av</sub> device 1183: 1.1 %	yes	936/21205926/ B from 22. July 2007
8.4.13 Difference sample/ calibration port	≤ 1.0 %	ΔX <sub>SC</sub> device 1177: ---- ΔX <sub>SC</sub> device 1183: ----	yes	936/21205926/ B from 22. July 2007
8.4.3 Response time (rise)	≤ 180 s	t <sub>r</sub> device 1177: max. 78 s t <sub>r</sub> device 1183: max. 80 s	yes	936/21205926/ B from 22. July 2007
8.4.3 Response time (fall)	≤ 180 s	t <sub>f</sub> device 1177: max. 80 s t <sub>f</sub> device 1183: max. 80 s	yes	936/21205926/ B from 22. July 2007
8.4.3 Difference rise time and fall time	≤ 10 s	t <sub>d</sub> device 1177: 3 s t <sub>d</sub> device 1183: 5 s	yes	Yes. refer to point 3
8.5.6 Period of unattended operation	3.0 months or less if manufacturer indicates a shorter period. but not less than 2 weeks	device 1177: 4 weeks device 1183: 4 weeks	yes	936/21205926/ B from 22. July 2007
8.5.7 Availability of the analyser	> 90 %	A <sub>a</sub> device 1177: 98.6 % A <sub>a</sub> device 1183: 98.6 %	yes	936/21205926/ B from 22. July 2007
8.5.5 Repeatability standard deviation under field conditions	≤ 5.0 % of the average of a three month period	S <sub>r,f</sub> device 1177: 4.80 % S <sub>r,f</sub> device 1183: 4.80 %	yes	936/21205926/ B from 22. July 2007
8.5.4 Long-term drift at zero	≤ 4.0 nmol/mol	D <sub>l,z</sub> device 1177: 1.06 ppb D <sub>l,z</sub> device 1183: 1.35 ppb	yes	Yes. refer to point 4
8.5.4 Long-term drift at span level	≤ 5.0 % of maximum of certification range	D <sub>l,s</sub> device 1177: max. 1.49 % D <sub>l,s</sub> device 1183: max. 1.56 %	yes	936/21205926/ B from 22. July 2007
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	D <sub>s,z</sub> device 1177: 0.0 ppb D <sub>s,z</sub> device 1183: 0.4 ppb	yes	936/21205926/ B from 22. July 2007
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	D <sub>s,s</sub> device 1177: -1.4 ppb D <sub>s,s</sub> device 1183: -1.4 ppb	yes	936/21218734/ A from 11. October 2012



## 2. Statement to test point "sensitivity coefficient of sample gas pressure"

[No. 8.4.7 of DIN EN 14212, test report 936/21205926/B from page 94]

As part of the revision of the standard DIN EN 14212 the minimum performance criteria of the test point "sensitivity coefficient of sample gas pressure" has been reduced from  $\leq 3.0$  nmol/mol/kPa (version 2005) to  $\leq 2.0$  nmol/mol/kPa (2012 version).

The sensitivity coefficients of the sample gas pressure determined within the type approval test are 0.02 ppb/kPa (device 1177) and 0.06 ppb/kPa (device 1183).

Therefore the minimum requirements of the standard DIN EN 14212 in the version of 2012 are also fulfilled.

### **3. Statement to test point “Difference between rise time and fall time“**

[No. 8.4.3 of DIN EN 14212, test report 936/21205926/B from page 79]

As part of the revision of the standard DIN EN 14212 the minimum performance criteria of the test point “difference between rise time and fall time“ has been changed from  $\leq 10\%$  relative difference or 10 s, depending on which value is the greater (version 2005), to the requirement of  $\leq 10$  s (2012 version).

The differences between rise and fall time determined within the type approval test are 3 s (device 1177) and 5 s (device1183).

Therefore the minimum requirements of the standard DIN EN 14212 in the version of 2012 are also fulfilled.

#### **4. Statement to the test point “Long-term drift at zero level“**

[No. 8.5.4 of DIN EN 14212, test report 936/21205926/B from page 114]

As part of the revision of the standard DIN EN 14212 the minimum performance criteria of the test point “Long-term drift at zero level“ has been reduced from  $\leq 5,0$  nmol/mol (version 2005) to 4.0 nmol/mol (version 2012).

The long-term drifts at zero level determined within the type approval test are 1.06 ppb (device 1177) and 1.35 ppb (device 1183).

Therefore the minimum requirements of the standard DIN EN 14212 in the version of 2012 are also fulfilled.

## 5. Update of the total uncertainty calculation according to Annex E of standard DIN EN 14212 (version November 2012)

[Annex E of DIN EN 14212, Addendum to test report 936/21218734/A from page 14]

The calculation of the total uncertainty was updated based on the new version of the standard DIN EN 14212, Annex E.

The performance criteria of DIN EN 14212 (version 2012) were fulfilled totally.

**Table 1: Combined uncertainty of results during the laboratory test of device 1 (SN 1177)**

Measuring device:		Teledyne API M100E / T100		Serial number:		SN 1 (1177)		
Measured component:		SO2		1h-Limit value:		132 nmol/mol		
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty		Square of partial uncertainty		
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.300	$u_{r,z}$	0.09	0.0079		
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	0.500	$u_{r,1h}$	0.15	0.0230		
3	"lack of fit" at 1h-limit value	≤ 4.0% of the meas. value	-0.400	$u_{l,1h}$	-0.30	0.0929		
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 3.0 nmol/mol/kPa	0.020	$u_{sp}$	0.53	0.2846		
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 1.0 nmol/mol/K	-0.013	$u_{gt}$	-0.10	0.0105		
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.050	$u_{st}$	0.39	0.1554		
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	-0.010	$u_v$	-0.11	0.0117		
8a	Interferent H <sub>2</sub> O with 21 nmol/mol	≤ 10 nmol/mol (Zero)	-0.400	$u_{H_2O}$	-1.28	1.6472		
		≤ 10 nmol/mol (Span)	-1.700					
8b	Interferent H <sub>2</sub> S with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	$u_{int,pos}$		11.8950		
		≤ 5.0 nmol/mol (Span)	0.900					
8c	Interferent NH <sub>3</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	or	3.45	11.8950		
		≤ 5.0 nmol/mol (Span)	0.100					
8d	Interferent NO with 500 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.500			11.8950		
		≤ 5.0 nmol/mol (Span)	3.200					
8e	Interferent NO <sub>2</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.010			11.8950		
		≤ 5.0 nmol/mol (Span)	0.500					
8f	Interferent m-Xylene with 1 µmol/mol	≤ 10 nmol/mol (Zero)	0.000	$u_{int,neg}$		11.8950		
		≤ 10 nmol/mol (Span)	1.200					
9	Averaging effect	≤ 7.0% of the meas. value	2.400	$u_{av}$	1.83	3.3454		
18	Difference sample/calibration port	≤ 1%	0.000	$u_{ssc}$	0.00	0.0000		
21	Uncertainty of test gas	≤ 3%	1.000	$u_{cg}$	0.66	0.4356		
				Combined standard uncertainty		$u_c$	4.2319	nmol/mol
				Expanded uncertainty		U	8.4639	nmol/mol
				Relative expanded uncertainty		W	6.41	%
				Maximum allowed expanded uncertainty		$W_{req}$	15	%

**Table 2: Combined uncertainty of results during the laboratory and field test of device 1 (SN 1177)**

Measuring device: Teledyne API M100E / T100		Serial number: SN 1 (1177)				
Measured component: SO2		1h-Limit value: 132 nmol/mol				
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty	Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.300	$u_{r,z}$	0.09	0.0079
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	0.500	$u_{r,h}$	not considered, as $u_{r,h} = 0.15 < u_{r,f}$	-
3	"lack of fit" at 1h-limit value	≤ 4.0% of the meas. value	-0.400	$u_{i,h}$	-0.30	0.0929
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 3.0 nmol/mol/kPa	0.020	$u_{sp}$	0.53	0.2846
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 1.0 nmol/mol/K	-0.013	$u_{st}$	-0.10	0.0105
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.050	$u_{st}$	0.39	0.1554
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	-0.010	$u_v$	-0.11	0.0117
8a	Interferent H <sub>2</sub> O with 21 nmol/mol	≤ 10 nmol/mol (Zero)	-0.400	$u_{H_2O}$	-1.28	1.6472
	Interferent H <sub>2</sub> O with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300			
8b	Interferent H <sub>2</sub> S with 200 nmol/mol	≤ 5.0 nmol/mol (Span)	0.900	$u_{int,pos}$	3.45	11.8950
8c	Interferent NH <sub>3</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300			
8d	Interferent NO with 500 nmol/mol	≤ 5.0 nmol/mol (Span)	0.100			
8e	Interferent NO <sub>2</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.500			
8f	Interferent m-Xylene with 1 μmol/mol	≤ 10 nmol/mol (Zero)	0.000	$u_{int,neg}$		
	Interferent m-Xylene with 1 μmol/mol	≤ 10 nmol/mol (Span)	1.200			
9	Averaging effect	≤ 7.0% of the meas. value	2.400	$u_{av}$	1.83	3.3454
10	Reproducibility standard deviation under field conditions	≤ 5.0% of 3 month average	4.800	$u_{r,f}$	6.34	40.1449
11	Long term drift at zero level	≤ 5.0 nmol/mol	1.060	$u_{d,LZ}$	0.61	0.3745
12	Long term drift at 1h-limit value	≤ 5.0% of max. of cert. range	1.490	$u_{d,1h}$	1.14	1.2894
18	Difference sample/calibration port	≤ 1%	0.000	$u_{sc}$	0.00	0.0000
21	Uncertainty of test gas	≤ 3%	1.000	$u_{cg}$	0.66	0.4356
Combined standard uncertainty				$u_c$	7.7263	nmol/mol
Expanded uncertainty				U	15.4525	nmol/mol
Relative expanded uncertainty				W	11.71	%
Maximum allowed expanded uncertainty				$W_{req}$	15	%

Addendum II to the type approval report of the measuring system  
 M100E (respective T100) for sulfur dioxide from Teledyne Advanced  
 Pollution Instrumentation, Report-No.: 936/21221556/A

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**Table 3: Combined uncertainty of results during the laboratory test of device 2 (SN 1183)**

Measuring device: Teledyne API M100E / T100		Serial number: SN 2 (1183)				
Measured component: SO <sub>2</sub>		1h-Limit value: 132 nmol/mol				
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty	Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.500	$u_{r,z}$ 0.15	0.0222	
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	0.900	$u_{r,1h}$ 0.27	0.0741	
3	"lack of fit" at 1h-limit value	≤ 4.0% of the meas. value	0.200	$u_{lf,1h}$ 0.15	0.0232	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 3.0 nmol/mol/kPa	0.060	$u_{sp}$ 1.60	2.5613	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.013	$u_{st}$ 0.10	0.0105	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.030	$u_{st}$ 0.24	0.0559	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.020	$u_v$ 0.22	0.0467	
8a	Interferent H <sub>2</sub> O with 21 nmol/mol	≤ 10 nmol/mol (Zero)	-0.100	$u_{i20}$ -1.21	1.4668	
		≤ 10 nmol/mol (Span)	-1.600			
8b	Interferent H <sub>2</sub> S with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.400	$u_{int,pos}$	12.6928	
		≤ 5.0 nmol/mol (Span)	0.400			
8c	Interferent NH <sub>3</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	or	3.56	
		≤ 5.0 nmol/mol (Span)	1.100			
8d	Interferent NO with 500 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.400	or	3.56	
		≤ 5.0 nmol/mol (Span)	2.900			
8e	Interferent NO <sub>2</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.100	$u_{int,neg}$	12.6928	
		≤ 5.0 nmol/mol (Span)	0.800			
8f	Interferent m-Xylene with 1 μmol/mol	≤ 10 nmol/mol (Zero)	0.300	or	3.56	
		≤ 10 nmol/mol (Span)	0.900			
9	Averaging effect	≤ 7.0% of the meas. value	1.100	$u_{av}$ 0.84	0.7028	
18	Difference sample/calibration port	≤ 1%	0.000	$u_{sc}$ 0.00	0.0000	
21	Uncertainty of test gas	≤ 3%	1.000	$u_{tg}$ 0.66	0.4356	
Combined standard uncertainty				$u_c$	4.2535	nmol/mol
Expanded uncertainty				U	8.5069	nmol/mol
Relative expanded uncertainty				W	6.44	%
Maximum allowed expanded uncertainty				$W_{req}$	15	%

**Table 4: Combined uncertainty of results during the laboratory and field test of device 2 (SN 1183)**

Measuring device: Teledyne API M100E / T100		Serial number: SN 2 (1183)				
Measured component: SO2		1h-Limit value: 132 nmol/mol				
No.	Performance characteristic	Performance criterion	Result	Partial uncertainty	Square of partial uncertainty	
1	Repeatability standard deviation at zero	≤ 1.0 nmol/mol	0.500	$u_{r,z}$	0.15	0.0222
2	Repeatability standard deviation at 1h-limit value	≤ 3.0 nmol/mol	0.900	$u_{r,1h}$	not considered, as $u_{r,1h} = 0.27 < u_{r,f}$	-
3	"lack of fit" at 1h-limit value	≤ 4.0% of the meas. value	0.200	$u_{l,1h}$	0.15	0.0232
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤ 3.0 nmol/mol/kPa	0.060	$u_{sp}$	1.60	2.5613
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.013	$u_{gt}$	0.10	0.0105
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤ 1.0 nmol/mol/K	0.030	$u_{st}$	0.24	0.0559
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤ 0.30 nmol/mol/V	0.020	$u_v$	0.22	0.0467
8a	Interferent H <sub>2</sub> O with 21 mmol/mol	≤ 10 nmol/mol (Zero)	-0.100	$u_{int,CO}$	-1.21	1.4668
		≤ 10 nmol/mol (Span)	-1.600			
8b	Interferent H <sub>2</sub> S with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.400	$u_{int,pos}$	3.56	12.6928
		≤ 5.0 nmol/mol (Span)	0.400			
8c	Interferent NH <sub>3</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.300	or	3.56	12.6928
		≤ 5.0 nmol/mol (Span)	1.100			
8d	Interferent NO with 500 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.400	or	3.56	12.6928
		≤ 5.0 nmol/mol (Span)	2.900			
8e	Interferent NO <sub>2</sub> with 200 nmol/mol	≤ 5.0 nmol/mol (Zero)	0.100	or	3.56	12.6928
		≤ 5.0 nmol/mol (Span)	0.800			
8f	Interferent m-Xylene with 1 µmol/mol	≤ 10 nmol/mol (Zero)	0.300	$u_{int,neg}$	0.84	0.7028
		≤ 10 nmol/mol (Span)	0.900			
9	Averaging effect	≤ 7.0% of the meas. value	1.100	$u_{av}$	0.84	0.7028
10	Reproducibility standard deviation under field conditions	≤ 5.0% of 3 month average	4.800	$u_{r,f}$	6.34	40.1449
11	Long term drift at zero level	≤ 5.0 nmol/mol	1.350	$u_{d,l,z}$	0.78	0.6075
12	Long term drift at 1h-limit value	≤ 5.0% of max. of cert. range	1.560	$u_{d,l,1h}$	1.19	1.4134
18	Difference sample/calibration port	≤ 1%	0.000	$u_{sp,c}$	0.00	0.0000
21	Uncertainty of test gas	≤ 3%	1.000	$u_{cg}$	0.66	0.4356
Combined standard uncertainty				$u_c$	7.7578	nmol/mol
Expanded uncertainty				U	15.5156	nmol/mol
Relative expanded uncertainty				W	11.75	%
Maximum allowed expanded uncertainty				$W_{req}$	15	%



# Operation Manual

## ***Model T100***

### ***UV Fluorescence SO<sub>2</sub> Analyzer***

Also supports operation of:

***Model T100U Analyzer***

***Model T100H Analyzer***

***Model T108 Analyzer***

***Model T108U Analyzer***

when used in conjunction with:

T100U addendum, PN 06840

T100H addendum, PN 07265

T108 addendum, PN 07268

T100U addendum, PN 06840, *and*  
T108 addendum, PN 07268

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## **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 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 GENERAL SAFETY HAZARD



The T100 Analyzer should only be used for the purpose and in the manner described in this manual. If you use the T100 in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

**NEVER** use any gas analyzer to sample combustible gas(es).

#### Note

Technical Assistance regarding the use and maintenance of the T100 or any other Teledyne API product can be obtained by contacting Teledyne API's Technical Support Department:

Phone: 800-324-5190

Email: [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

or by accessing various service options on our website at

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

## CONSIGNES DE SÉCURITÉ

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



**AVERTISSEMENT** : Risque de choc électrique



**DANGER** : Oxydant puissant



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



**MISE EN GARDE** : Surface chaude



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



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



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

### MISE EN GARDE



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

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

## WARRANTY

### WARRANTY POLICY (02024H)

Teledyne Advanced Pollution Instrumentation (TAPI), a business unit of Teledyne Instruments, Inc., provides that:

Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available. (For the instrument-specific warranty period, please refer to the “Limited Warranty” section in the Terms and Conditions of Sale on our website at the following link: [http://www.teledyne-api.com/terms\\_and\\_conditions.asp](http://www.teledyne-api.com/terms_and_conditions.asp)).

### COVERAGE

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

### NON-TAPI MANUFACTURED EQUIPMENT

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

### PRODUCT RETURN

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

The complete Terms and Conditions of Sale can be reviewed at [http://www.teledyne-api.com/terms\\_and\\_conditions.asp](http://www.teledyne-api.com/terms_and_conditions.asp)

#### CAUTION – Avoid Warranty Invalidation



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

## ABOUT THIS MANUAL

Presented here is information regarding the documents that are included with this manual (Structure), its history of release and revisions (Revision History), how the content is organized (Organization), and the conventions used to present the information in this manual (Conventions Used).

### STRUCTURE

This T100 manual, PN 06807, is comprised of multiple documents, assembled in PDF format, as listed below.

Part No.	Rev	Name/Description
06807	E	Operation Manual, T100 UV Fluorescence SO <sub>2</sub> Analyzer
05036	F	Appendix A, Menu Trees and related software documentation
06845	A	Spare Parts List (in Appendix B of this manual)
04357	A	AKIT, Expendables, basic (in Appendix B of this manual)
01475	A	AKIT, Expendables, IZS (in Appendix B of this manual)
04728	A	AKIT, Spares (in Appendix B of this manual)
04796	F	Appendix C, Repair Form
06908	A	Interconnect Diagram (in Appendix D of this manual)

#### Note

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

### CONVENTIONS USED

In addition to the safety symbols as presented in the *Important Safety Information* page, this manual provides *special notices* related to the safety and effective use of the analyzer and other pertinent information.

**Special Notices** appear as follows:

#### ATTENTION

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**  
**This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.**  
-----

#### IMPORTANT

-----  
**IMPACT ON READINGS OR DATA**  
**Could either affect accuracy of instrument readings or cause loss of data.**  
-----

#### Note

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

## REVISION HISTORY

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

<b>T100 Manual, PN06807</b>			
<b>Date</b>	<b>Rev</b>	<b>DCN</b>	<b>Change Summary</b>
2016 April 19	E	7230	Clarified Range setup when using dilution factor option; other administrative fixes.
2015 June 28	D	7088	Condensed content; implemented DCRs
2013 Apr 22	C	6650	Administrative corrections; technical corrections
2011 Aug 22	B	6192	Administrative change: reorganized structure. Technical Updates: added MODBUS Quick Setup (Section 6.6.1), update Appendices A and D with latest revisions.
2010 Sep 7	A	5834	Initial release

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# 1. INTRODUCTION, FEATURES AND OPTIONS

This section provides an overview of the Teledyne API Model T100 Analyzer, its features and its options.

## 1.1. T100 OVERVIEW

The Model T100 (also referred to as T100) UV Fluorescence SO<sub>2</sub> Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO<sub>2</sub>), in a sample gas drawn through the instrument's sample chamber where it is exposed to ultraviolet light, which causes any SO<sub>2</sub> present to fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO<sub>2</sub> present in the sample gas.

The T100's exceptional stability is achieved with the use of an optical shutter to compensate for sensor drift and a reference detector to correct for changes in UV lamp intensity. Additionally, an advanced optical design combined with a special scrubber, called a "kicker" that removes hydrocarbons (which fluoresce similarly to SO<sub>2</sub>), to prevent inaccuracies caused by interferents.

Calibration is performed in software that stores SO<sub>2</sub> concentration measurements made when specific, known concentrations of SO<sub>2</sub> are supplied to the analyzer. The microprocessor uses these calibration values along with other performance parameters such as the sensor offset, UV lamp intensity, amount of stray light present, and sample gas temperature and pressure measurements to compute the final SO<sub>2</sub> concentration.

Built-in data acquisition capability, using the analyzer's internal memory, allows the logging of multiple parameters including averaged or instantaneous concentration values, calibration data, and operating parameters such as pressure and flow rate. Stored data are easily retrieved through the serial port or Ethernet port via our APICOM software or from the front panel, allowing operators to perform predictive diagnostics and enhanced data analysis by tracking parameter trends. Multiple averaging periods of one minute to 365 days are available for over a period of one year.

## 1.2. FEATURES

The features of your T100 UV Fluorescence Sulfur Dioxide Analyzer include:

- LCD Graphical User Interface with capacitive touch screen
- Ranges, 0-50 ppb to 0-20,000 ppb, user selectable
- Dual ranges and auto ranging
- Microprocessor control for versatility
- Multi-tasking software to allow viewing test variables while operating
- Continuous self checking with alarms
- Bi-directional USB, RS-232, and 10/100Base-T Ethernet ports for remote operation (optional RS-485)
- Front panel USB ports for peripheral devices
- Digital status outputs to indicate instrument operating conditions
- Adaptive signal filtering to optimize response time
- Temperature and Pressure compensation
- Internal Zero and Span check (optional)
- Internal data logging with 1 min to 365 day multiple averages
- Critical flow orifices to provide flow stability

## 1.3. T100 DOCUMENTATION


In addition to this operation manual (part number 06807), the APICOM and DAS manual (PN 07463) is available for download from Teledyne API's website at <http://www.teledyne-api.com/manuals/>, to support the operation of this instrument.

## 1.4. OPTIONS

The options available for your analyzer are presented in Table 1-1. To order these options or to learn more about them, please contact the Sales department of Teledyne Advanced Pollution Instruments at:

TOLL-FREE:	800-324-5190
TEL:	+1 858-657-9800
FAX:	+1 858-657-9816
E-MAIL:	Api-sales@teledyne.com
WEB SITE:	<a href="http://www.teledyne-api.com/">http://www.teledyne-api.com/</a>

Table 1-1: Analyzer Options

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
<b>Pumps</b>		<b>Pumps meet all typical AC power supply standards while exhibiting same pneumatic performance.</b>	
	10A	External Pump 100V - 120V @ 60 Hz	N/A
	10B	External Pump 220V - 240V @ 50 Hz	N/A
	10C	External Pump 220V - 240V @ 60 Hz	N/A
	10D	External Pump 100V - 120V @ 50 Hz	N/A
	10E	External Pump 100V @ 60 Hz	N/A
	11B	Pumpless, internal or external Pump Pack	N/A
	13	High Voltage Internal Pump 240V @ 50Hz	N/A
<b>Rack Mount Kits</b>		<b>Options for mounting the analyzer in standard 19" racks</b>	
	20A	Rack mount brackets with 26 in. chassis slides	N/A
	20B	Rack mount brackets with 24 in. chassis slides	N/A
	21	Rack mount brackets only (compatible with carrying strap, Option 29)	N/A
	23	Rack mount for external pump pack (no slides)	N/A
<b>Carrying Strap/Handle</b>		<b>Side-mounted strap for hand-carrying analyzer</b>	
	29	Extends from "flat" position to accommodate hand for carrying. Recesses to 9mm (3/8") dimension for storage. Can be used with rack mount brackets, Option 21. Cannot be used with rack mount slides.	N/A
		<b>CAUTION</b> <b>General Safety Hazard</b>	
		<b>A FULLY LOADED T100 WITH VALVE OPTIONS WEIGHS ABOUT 18 KG (40 POUNDS).</b> To avoid personal injury we recommend that two persons lift and carry the analyzer. Disconnect all cables and tubing from the analyzer before moving it.	
<b>Analog Inputs</b>		Used for connecting external voltage signals from other instrumentation (such as meteorological instruments).	
	64	Also can be used for logging these signals in the analyzer's internal DAS	Sections 3.3.1.2, 5.3, 5.9.3.7, and 7
<b>Current Loop Analog Outputs</b>		<b>Adds isolated, voltage-to-current conversion circuitry to the analyzer's analog outputs.</b>	
	41	Can be configured for any output range between 0 and 20 mA. May be ordered separately for any of the analog outputs. Can be installed at the factory or retrofitted in the field.	Sections 3.3.1.4, 5.4.1, 5.9.3, and 5.9.3.5
<b>Parts Kits</b>		<b>Spare parts and expendables</b>	
	42A	<b>Expendables Kit</b> includes a recommended set of expendables for one year of operation of this instrument including replacement sample particulate filters.	Appendix B
	43	<b>Expendables Kit with IZS</b> includes the items needed to refurbish the internal zero air scrubber (IZS) that is included.	Appendix B
	45	<b>Spare Parts Kit</b> includes spares parts for one unit.	Appendix B
<b>NO Optical Filter</b>		<b>Recommended for high NOX backgrounds.</b>	
	47	Required for EN Certification.	N/A

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE		
<b>Calibration Valves</b>		<b>Used to control the flow of calibration gases generated from external sources, rather than manually switching the rear panel pneumatic connections.</b>			
	50A	Two Teflon® solenoid valve sets located inside the analyzer: <b>Zero/Span</b> valve switches between zero air and span gas; <b>Sample/Cal</b> valve switches between sample gas and calibration gas.	Sections 3.3.2.3, 3.3.2.4, 9.4, 9.5 and 9.6		
<b>Internal Zero/Span (IZS) Gas Generator</b>		<b>Generates internal zero air and span gas.</b>			
	51A	Includes heated enclosure for a permeation tube (tube not included – see SO <sub>2</sub> IZS Permeation Tubes options), an external scrubber for producing zero air and a set of valves for switching between the sample gas inlet and the output of the zero/span subsystem, functionally very similar to the valves included in the zero/span valve option.	Sections 3.3.2.4, 9.5, 10.3.2 and 11.6.17		
<b>SO<sub>2</sub> IZS Permeation Tubes</b>		<b>Replacement tubes for the IZS option; identical size/shape; different effusion rates.</b>			
		Effusion Rate (@ 50°C)	Approximate Concentration	Specified Flow Rate (of indicated perm tube rate)	
	52C	796 ng/min	0.3-0.5 ppm	0.76 ± 5% lpm	N/A
	52H	1592 ng/min	0.8 ppm	0.76 ± 50% lpm	N/A
	52M	220 ng/min	150 ppb	0.56 ± 25% lpm	N/A
		Each tube comes with a calibration certificate, traceable to a NIST standard, specifying its actual effusion rate of that tube to within ± 5% when immersed in a gas stream moving at the specified flow rate. This calibration is performed at a tube temperature of 50°C.			Sections 3.3.2.4 and 9.1.1.3
<b>Communication Cables</b>		<b>For remote serial, network and Internet communication with the analyzer.</b>			
		Type	Description		
	60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with DB-25 serial connectors.		
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.		
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.		
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.		
<b>Concentration Alarm Relay</b>		<b>Issues warning when gas concentration exceeds limits set by user.</b>			
	61	Four (4) “dry contact” relays on the rear panel of the instrument. This relay option is different from and in addition to the “Contact Closures” that come standard on all TAPI instruments.			Sections 3.3.1.7 and 3.4.4
<b>RS-232 Multidrop</b>		<b>Enables communications between host computer and up to eight analyzers.</b>			
	62	Multidrop card seated on the analyzer’s CPU card. Each instrument in the multidrop network requires this card and a communications cable (Option 60B).			Section 3.3.1.8

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
<b>Second Gas Sensors</b>		<b>Choice of one additional gas sensor.</b>	
	65A	Oxygen (O <sub>2</sub> ) Sensor	<ul style="list-style-type: none"> <li>• Section 2.1 (specs)</li> <li>• Section 3.3.2.9, (pneumatic layout)</li> <li>• Section 9.10.1 (calibration)</li> <li>• Section 12.2 for principles of operation</li> </ul>
	67A	Carbon Dioxide (CO <sub>2</sub> ) Sensor	<ul style="list-style-type: none"> <li>• Section 2.1 (specs)</li> <li>• Section 3.3.2.10 (pneumatic layout)</li> <li>• Section 9.10.2 (calibration)</li> <li>• Section 12.3 (principles of operation)</li> </ul>
<b>Special Features</b>		<b>Built in features, software activated</b>	
	N/A	<p><b>Maintenance Mode Switch</b>, located inside the instrument, places the analyzer in maintenance mode where it can continue sampling, yet ignore calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop or Hessen protocol networks.</p> <p>Call Technical Support for activation.</p>	N/A
	N/A	<p><b>Second Language Switch</b> activates an alternate set of display messages in a language other than the instrument's default language. Call Technical Support for a specially programmed Disk on Module containing the second language.</p>	N/A
	N/A	<p><b>Dilution Ratio Option</b> allows the user to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas.</p> <p>Call Technical Support for activation.</p>	Section 3.4.4.1, 5.4.5 and 12.1.9.3

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## 2. SPECIFICATIONS, APPROVALS & COMPLIANCE

This section presents specifications for the T100 analyzer and the O<sub>2</sub> and CO<sub>2</sub> sensor options, Agency approvals, EPA equivalency designation, and CE mark compliance.

### 2.1. SPECIFICATIONS AND APPROVALS

**Table 2-1 T100 Basic Unit Specifications**

Parameter	Description	
Ranges (Physical Analog Output)	Min: 0-50 ppb Full Scale Max: 0-20,000 ppb Full Scale (selectable, dual ranges and auto ranging supported)	
Measurement Units	ppb, ppm, µg/m <sup>3</sup> , mg/m <sup>3</sup> (selectable)	
Zero Noise <sup>1</sup>	< 0.2 ppb (RMS)	
Span Noise <sup>1</sup>	< 0.5% of reading, above 50 ppb	
Lower Detectable Limit <sup>2</sup>	0.4 ppb	
Zero Drift	< 0.5 ppb/24 hours	
Span Drift	< 0.5% of full scale/24 hours	
Lag Time <sup>1</sup>	20 seconds	
Rise/Fall Time <sup>1</sup>	<100 sec to 95%	
Linearity	1% of full scale	
Precision <sup>1</sup>	0.5% of reading above 50 ppb	
Sample Flow Rate	650 cm <sup>3</sup> /min. ±10%	
Power Requirements	Power Rating 110-120 V~, 60 Hz 3.0A 220-240 V~, 50/60 Hz 3.0A	Typical Power Consumption 165W 140W
Analog Output Ranges	10 V, 5 V, 1 V, 0.1 V (selectable)	
Recorder Offset	± 10 %	
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital outputs 6 opto-isolated digital inputs 4 analog outputs	
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs	

Parameter	Description
Environmental	Installation category (over-voltage category) II; Pollution degree 2 Intended for Indoor use only at altitudes ≤ 2000m
Operating Temperature	5 - 40 °C (with EPA Equivalency)
Humidity Range	0 - 95% RH, non-condensing
Dimensions HxWxD	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)
Weight	31 lbs (14 kg); 35.7 lbs (16.2 kg) with internal pump
<sup>1</sup> As defined by the USEPA.	
<sup>2</sup> Defined as twice the zero noise level by the USEPA.	

**Table 2-2: O<sub>2</sub> Sensor Option Specifications**

Parameter	Description
Ranges	0-1% to 0-100% user selectable. Dual ranges and auto-ranging supported.
Zero Noise <sup>1</sup>	<0.02% O <sub>2</sub>
Lower Detectable Limit <sup>2</sup>	<0.04% O <sub>2</sub>
Zero Drift (24 hours) <sup>3</sup>	<± 0.02% O <sub>2</sub>
Zero Drift (7 days)	<± 0.05% O <sub>2</sub>
Span Noise <sup>1</sup>	<± 0.05% O <sub>2</sub>
Span Drift (7 days)	<± 0.1% O <sub>2</sub>
Accuracy	(intrinsic error) <± 0.1% O <sub>2</sub>
Linearity	<± 0.1 % O <sub>2</sub>
Temp Coefficient	<± 0.05% O <sub>2</sub> /°C,
Rise and Fall Time	<60 seconds to 95%
<sup>1</sup> As defined by the USEPA	
<sup>2</sup> Defined as twice the zero noise level by the USEPA	
<sup>3</sup> Note: zero drift is typically <± 0.1% O <sub>2</sub> during the first 24 hrs of operation	

**Table 2-3: CO<sub>2</sub> Sensor Option Specifications**

Parameter	Description
Ranges	0-1% to 0-20% user selectable. Dual ranges and auto-ranging supported.
Zero Noise <sup>1</sup>	<0.02% CO <sub>2</sub>
Zero Drift (24 hours)	<± 0.02% CO <sub>2</sub>
Zero Drift (7 days)	<± 0.05% CO <sub>2</sub>
Span Noise <sup>1</sup>	<± 0.1% CO <sub>2</sub>
Span Drift (7 days)	<± 0.1% CO <sub>2</sub>
Lower Detectable Limit <sup>2</sup>	<0.04% CO <sub>2</sub>
Accuracy	<± (0.02% CO <sub>2</sub> + 2% of reading)
Linearity	<± 0.1% CO <sub>2</sub>
Temperature Coefficient	<± 0.01% CO <sub>2</sub> /°C
Rise and Fall Time	<60 seconds to 95%
<sup>1</sup> As defined by the USEPA	
<sup>2</sup> Defined as twice the zero noise level by the USEPA	



## 2.2. EPA EQUIVALENCY DESIGNATION

The Model T100 Fluorescence SO<sub>2</sub> Analyzer is officially designated as US EPA Federal Equivalent Method Number EQSA-0495-100 for sulfur dioxide measurement. The official List of Designated Reference and Equivalent Methods is published in the U.S. Federal Register: <http://www3.epa.gov/ttn/amtic/criteria.html>.

## 2.3. APPROVALS AND CERTIFICATIONS

The Teledyne API Model T100 analyzer was tested and certified for Safety and Electromagnetic Compatibility (EMC). This section presents the compliance statements for those requirements and directives.

### 2.3.1. EMC

EN 61326-1 (IEC 61326-1), Class A Emissions/Industrial Immunity  
EN 55011 (CISPR 11), Group 1, Class A Emissions  
FCC 47 CFR Part 15B, Class A Emissions  
**CE:** 2004/108/EC, Electromagnetic Compatibility Directive

### 2.3.2. SAFETY

IEC 61010-1:2010 (3<sup>rd</sup> Edition), Safety requirements for electrical equipment for measurement, control, and laboratory use.  
**CE:** 2006/95/EC, Low-Voltage Directive

### 2.3.3. OTHER TYPE CERTIFICATIONS

MCERTS: Sira MC 050067/07  
EN 15267 – Air Quality – Ambient Air Automated Measuring Systems  
EN 14212 – Ambient Air Measurement for SO<sub>2</sub>  
For additional certifications, please contact Technical Support:

**Toll-free Phone:** 800-324-5190  
**Phone:** 858-657-9800  
**Fax:** 858-657-9816  
**Email:** [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

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## 3. GETTING STARTED

This section addresses the procedures for unpacking the instrument and inspecting for damage, presents clearance specifications for proper ventilation, introduces the instrument layout, then presents the procedures for getting started: making electrical and pneumatic connections, and conducting an initial calibration check.

### 3.1. UNPACKING THE T100 ANALYZER



**CAUTION  
GENERAL SAFETY HAZARD**

Avoid personal injury: always use two persons to lift and carry the T100.

**ATTENTION**

**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

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



**CAUTION**

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

**Note**

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

Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.

Included with your analyzer is a printed record of the final performance characterization performed on your instrument at the factory. It is titled *Final Test and Validation Data Sheet (P/N 04551)*. This record is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

With no power to the unit, carefully remove the top cover of the analyzer and check for internal shipping damage by carrying out the following steps:

1. Remove the two flat head, Phillips screws on the sides of the instrument;
2. Slide the cover backwards until it clears the analyzer's front bezel, and;
3. Lift the cover straight up.
4. Inspect the interior of the instrument to ensure that 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 that they are firmly and properly seated.
6. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the analyzer.



**WARNING  
ELECTRICAL SHOCK HAZARD**

**Never disconnect PCAs, wiring harnesses or electronic subassemblies while under power.**

### 3.1.1. VENTILATION CLEARANCE

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

**Table 3-1: Ventilation Clearance**

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	<b>4 in.</b>
Sides of the instrument	<b>1 in.</b>
Above and below the instrument	<b>1 in.</b>

Various rack mount kits are available for this analyzer. Refer to Section 1.4 of this manual for more information.

## 3.2. INSTRUMENT LAYOUT

Instrument layout includes illustrations and descriptions of front panel and display, rear panel connectors, and internal chassis layout.

### 3.2.1. FRONT PANEL

Figure 3-1 shows the analyzer's front panel layout, followed by a close-up of the display screen in Figure 3-2, which is described in Table 3-2. 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 touchscreen interface
- thumb drive (not included) to download updates to instruction software (contact TAPI Technical Support for information).

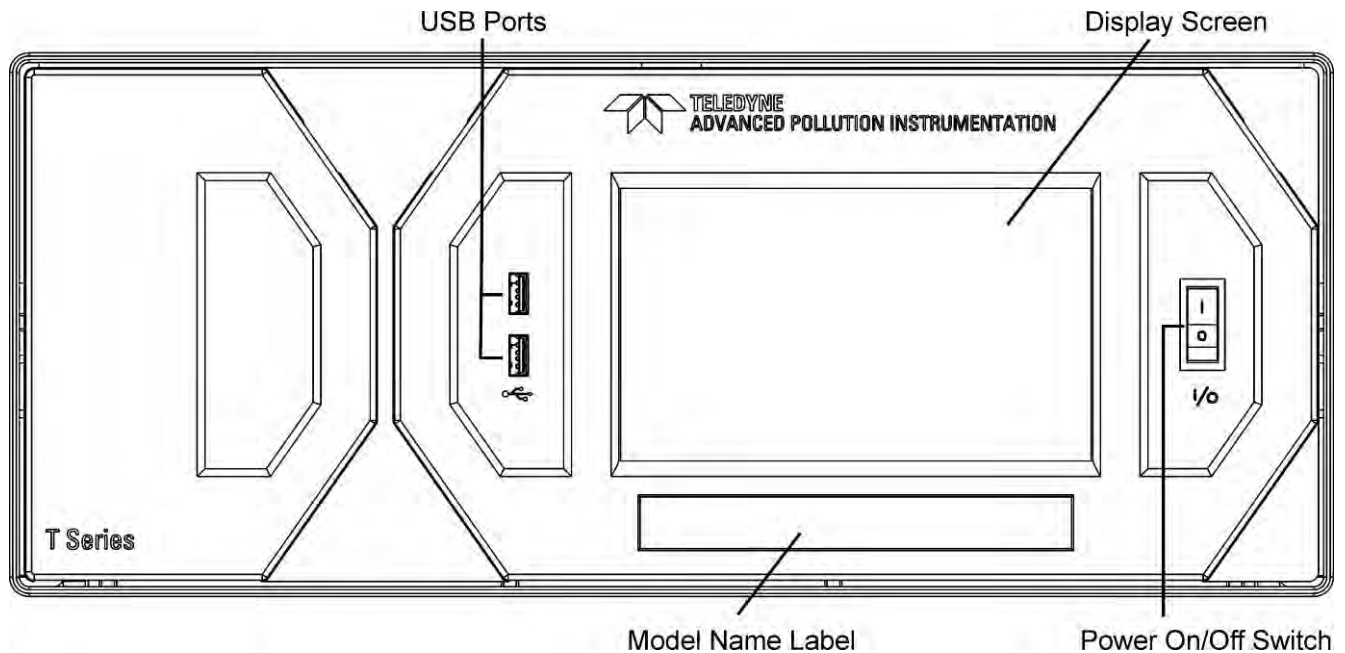


Figure 3-1: Front Panel Layout



Figure 3-2: Display Screen and Touch Control

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

#### ATTENTION

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**  
 Do not use hard-surfaced instruments such as pens to touch the control buttons.  
 -----

Table 3-2: Display Screen and Touch Control Description

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

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

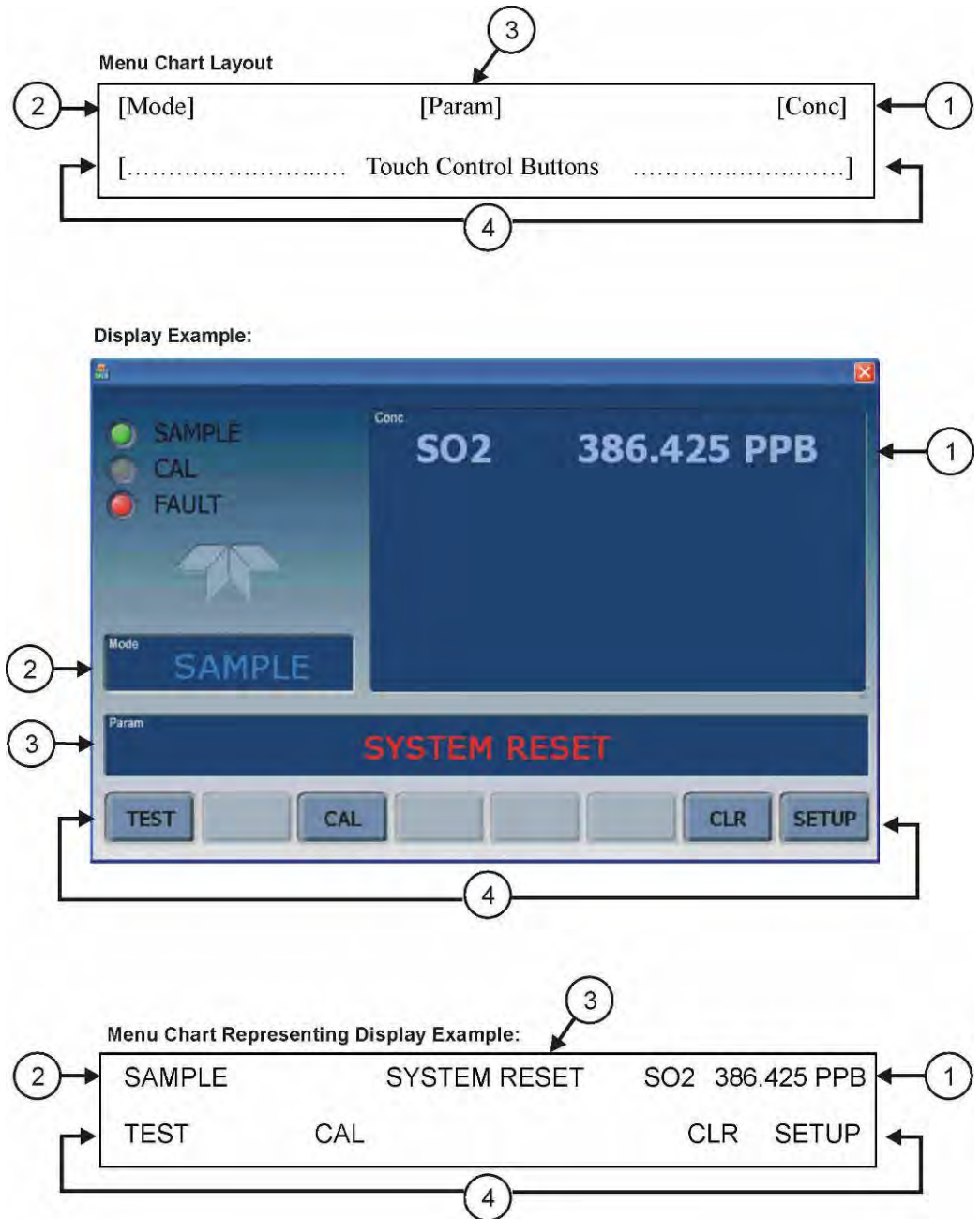


Figure 3-3: Display/Touch Control Screen Mapped to Menu Charts

**Note**

The menu charts in this manual contain condensed representations of the analyzer’s display during the various operations being described. These menu charts are not intended to be exact visual representations of the actual display.



### 3.2.2. REAR PANEL

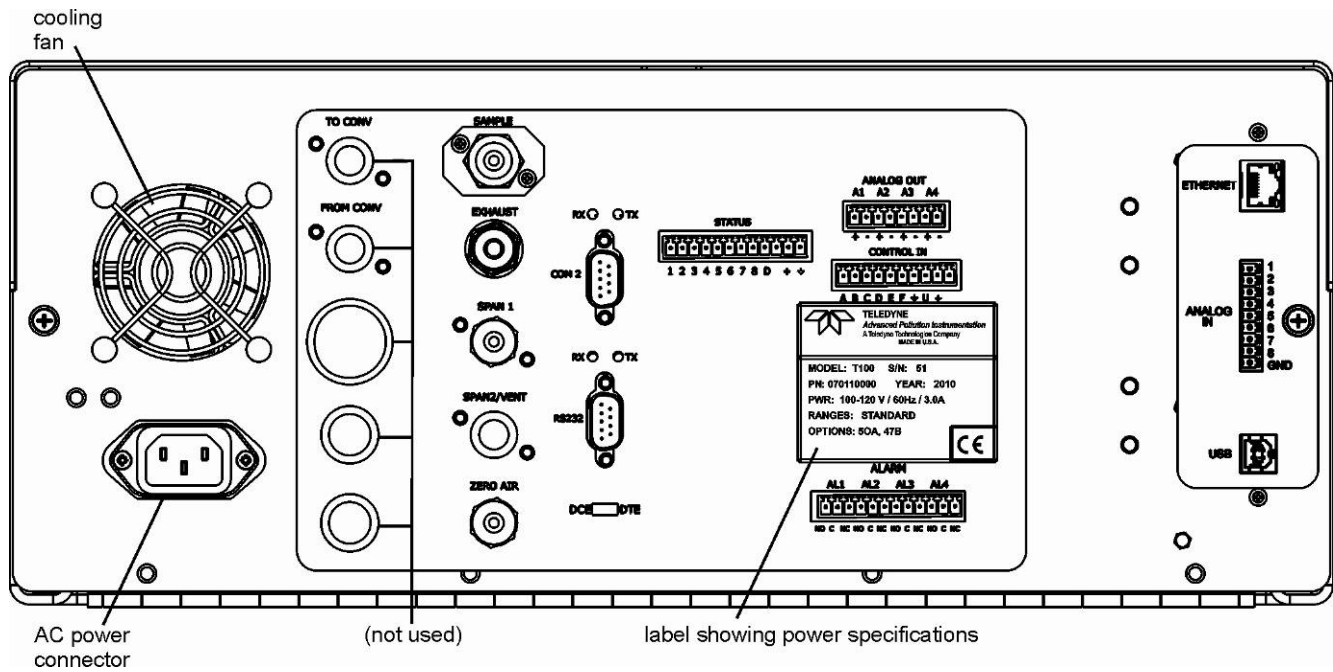



Figure 3-4: Rear Panel Layout

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

Table 3-3: Rear Panel Description

Component	Function
<b>cooling fan</b>	Pulls ambient air into chassis through side vents and exhausts through rear.
 <b>AC power connector</b>	Connector for three-prong cord to apply AC power to the analyzer. <b>CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label</b>
<b>Model/specs label</b>	Identifies the analyzer model number and provides power specs
<b>TO CONV</b>	(not used in this model)
<b>FROM CONV</b>	(not used in this model)
<b>SAMPLE</b>	Connect a gas line from the source of sample gas here. Calibration gases are also inlet here on units without zero/span/shutoff valve options installed.
<b>EXHAUST</b>	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument.
<b>SPAN 1</b>	On units with zero/span/shutoff valve options installed, connect a gas line to the source of calibrated span gas here.
<b>SPAN2/VENT</b>	Used as a second cal gas input line when instrument is configured with zero/span valves and a dual gas option, or as a cal gas vent line when instrument is configured with a pressurized span option ( <i>Call factory for details</i> ).
<b>ZERO AIR</b>	Internal Zero Air: On units with zero/span/shutoff valve options installed but no internal zero air scrubber attach a gas line to the source of zero air here.
<b>RX TX</b>	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
<b>COM 2</b>	Serial communications port for RS-232 or RS-485.
<b>RS-232</b>	Serial communications port for RS-232 only.
<b>DCE DTE</b>	Switch to select either data terminal equipment or data communication equipment during RS-232 communication. (Section 6.1).
<b>STATUS</b>	For outputs to devices such as Programmable Logic Controllers (PLCs).
<b>ANALOG OUT</b>	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
<b>CONTROL IN</b>	For remotely activating the zero and span calibration modes.
<b>ALARM</b>	Option for concentration alarms and system warnings.
<b>ETHERNET</b>	Connector for network or Internet remote communication, using Ethernet cable
<b>ANALOG IN</b>	Option for external voltage signals from other instrumentation and for logging these signals
<b>USB</b>	Connector for direct connection to personal computer, using USB cable.
<b>Information Label</b>	Includes voltage and frequency specifications

### 3.2.3. INTERNAL CHASSIS LAYOUT

Figure 3-5 illustrates the internal layout of the chassis without options. Section 3.3.2 shows pneumatic diagrams for the basic configuration and for options.

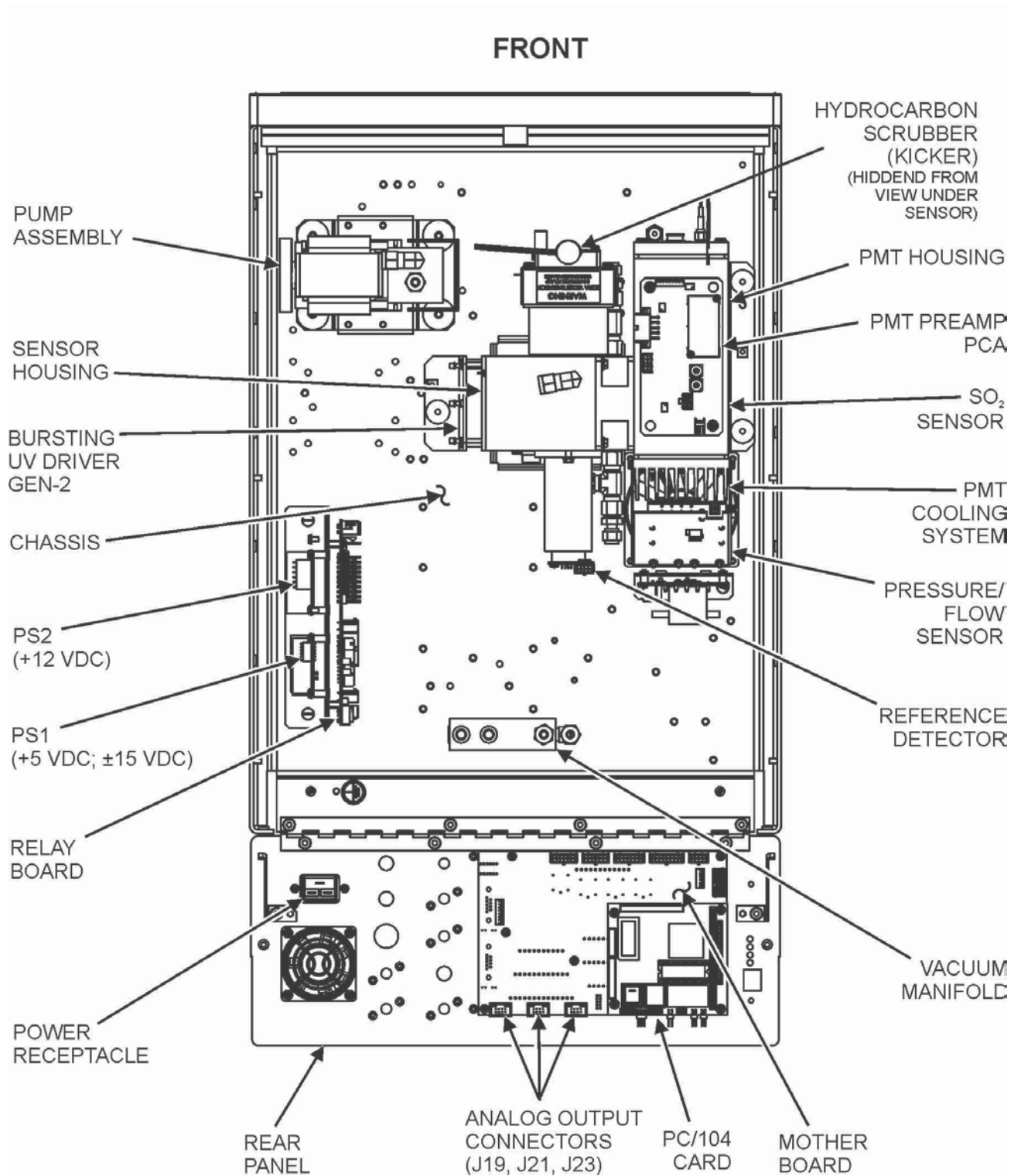


Figure 3-5: Internal Layout, Basic (no Valve or Second Gas Options)

### 3.3. CONNECTIONS AND SETUP

This section presents the electrical (Section 3.3.1) and pneumatic (Section 3.3.2) connections for setup and preparing for instrument operation.

#### 3.3.1. ELECTRICAL CONNECTIONS

**Note**

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

This section provides instructions for basic connections and for options. Table 3-4 provides a direct link to the instructions for the subsections that apply to your analyzer's configuration.

**Table 3-4: Electrical Connections References**

Connection	Section
Power	3.3.1.1
Analog Inputs (Option)	3.3.1.2
Analog Outputs	3.3.1.3
Current Loop Analog Outputs (Option), and converting current to voltage output	3.3.1.4
Status Outputs	3.3.1.5
Control Inputs	3.3.1.6
Concentration Alarm Relay (Option)	3.3.1.7
Communications (Ethernet, USB, RS-232, Multidrop, RS-485)*	3.3.1.8
* USB is an option with exceptions. * RS-485 is an option and requires special setup (contact the Factory). Either USB or RS-485 can be used; not both.	

### 3.3.1.1. CONNECTING POWER

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



#### WARNING ELECTRICAL SHOCK HAZARD

High Voltages are present inside the analyzer's case.  
Power connection must have functioning ground connection.  
Do not defeat the ground wire on power plug.  
Power off analyzer before disconnecting or connecting electrical subassemblies.  
Do not operate analyzer with the cover off.



#### CAUTION GENERAL SAFETY HAZARD

To avoid damage to your analyzer, ensure that the AC power voltage matches the voltage indicated on the Analyzer's model identification label on the rear panel before plugging the T100 into line power.

### 3.3.1.2. CONNECTING ANALOG INPUTS (OPTION)

The Analog In connector is used for connecting external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal Data Acquisition System (DAS). The input voltage range for each analog input is 1-10 VDC, and input impedance is nominally 20k $\Omega$  in parallel with 0.1 $\mu$ F.

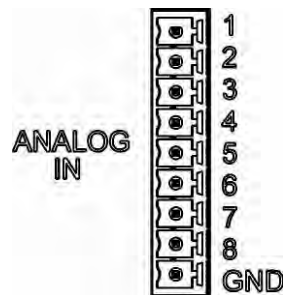


Figure 3-6: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 3-5 .

**Table 3-5: Analog Input Pin Assignments**

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

<sup>1</sup> See Section 7 for details on setting up the DAS.

### 3.3.1.3. CONNECTING ANALOG OUTPUTS

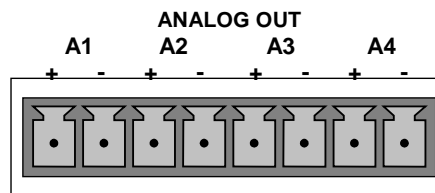
The T100 is equipped with several analog output channels accessible through a connector on the rear panel of the instrument. The standard configuration for these outputs is mVDC. An optional current loop output is available for each (Section 3.3.1.4).

In default configuration, Channels A1 and A2 output a signal proportional to the SO<sub>2</sub> concentration of the sample gas. Either can be used for connecting the analog output signal to a chart recorder or for interfacing with a datalogger.

Channel A3 is only used on the T100 if the optional O<sub>2</sub> or CO<sub>2</sub> sensor is installed.

Channel A4 is special. It can be set by the user (refer to Section 5.9.9) to output any one of the parameters accessible through the <TST TST> buttons of the unit's sample display.

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 analyzer.

**Figure 3-7: Analog Output Connector**

**Table 3-6: Analog Output Pin Assignments**

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3 (Only used if an optional O <sub>2</sub> or CO <sub>2</sub> sensor is installed)	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	I Out +
8		Ground	I Out -

### 3.3.1.4. CURRENT LOOP ANALOG OUTPUTS (OPTION 41) SETUP

If your analyzer had this option installed at the factory, there are no further connections to be made. The current loop option can be configured for any output range between 0 and 20 mA. Section 5.9.3.5 provides information on calibrating or adjusting these outputs.

This section provides instructions for setting up the analog outputs for voltage and/or current output. Figure 3-8 provides installation instructions and illustrates a sample combination of one current output and two voltage outputs configuration.

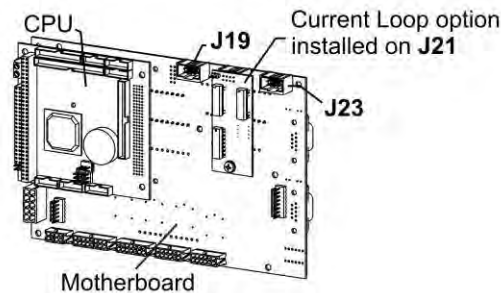
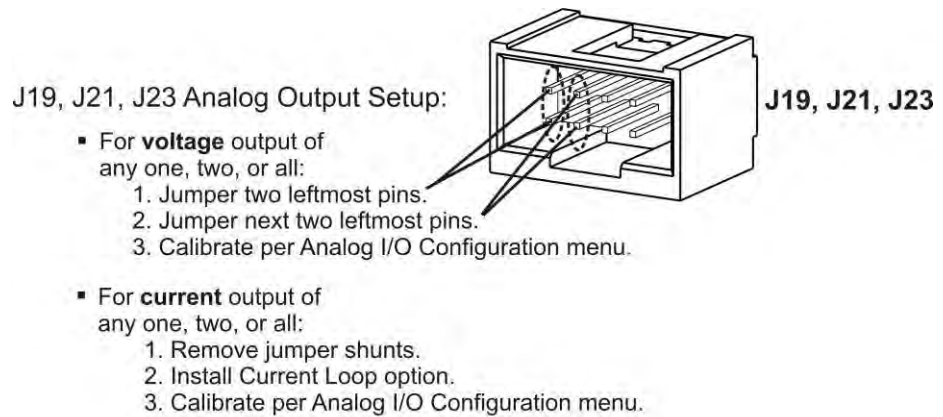
- For current output install the Current Loop option PCA on J19, on J21 or on J23 of the motherboard.
- For voltage output, install jumpers on J19, J21 and/or J23.

Following Figure 3-8 are instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs.

#### CAUTION – AVOID INVALIDATING WARRANTY



**Servicing or handling of circuit components requires electrostatic discharge protection (ESD), i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to the manual on Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.**



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

**Figure 3-8: Current Loop Option Installed on the Motherboard**

### CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

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

1. Turn off power to the analyzer.
2. If a recording device was connected to the output being modified, disconnect it.
3. Remove the top cover
  - Remove the side-panel screw fastening the top cover to the unit.
  - Lift the cover straight up.
4. Disconnect the current loop option PCA from the appropriate connector on the motherboard (refer to Figure 3-8).
5. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left most pins and the second shunt on the two pins next to it (refer to Figure 3-8).
6. Reattach the top case to the analyzer.

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

Calibrate the analog output as described in Section 5.9.3



### 3.3.1.5. CONNECTING THE STATUS OUTPUTS

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

#### ATTENTION

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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

The status outputs are accessed via a 12-pin connector on the analyzer’s rear panel labeled STATUS (Figure 3-9). Pin-outs for this connector are presented in Table 3-7.

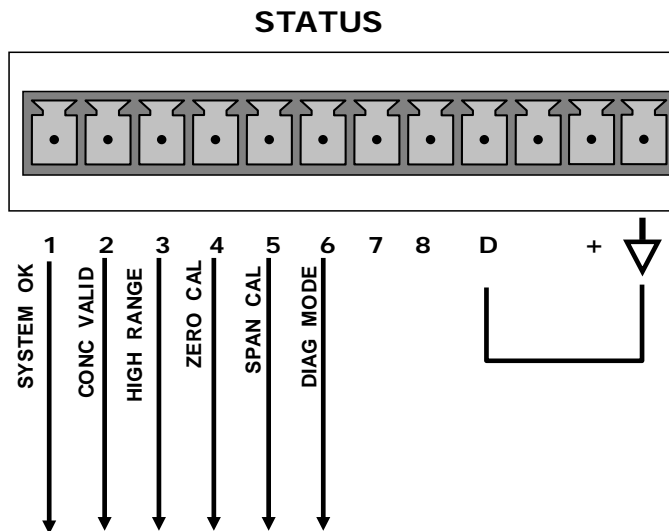



Figure 3-9: Status Output Connector

Table 3-7: Status Output Signals

REAR PANEL LABEL	STATUS DEFINITION	CONDITION
1	SYSTEM OK	ON if no faults are present.
2	CONC VALID	OFF any time the <b>HOLD OFF</b> feature is active, such as during calibration or when other faults exist possibly invalidating the current concentration measurement (example: sample flow rate is outside of acceptable limits). ON if concentration measurement is valid.
3	HIGH RANGE	ON if unit is in high range of either the DUAL or Auto range modes.
4	ZERO CAL	ON whenever the instrument's <b>ZERO</b> point is being calibrated.
5	SPAN CAL	ON whenever the instrument's <b>SPAN</b> point is being calibrated.
6	DIAG MODE	ON whenever the instrument is in <b>DIAGNOSTIC</b> mode
7&8	SPARE	
D	EMITTER BUS	The emitters of the transistors on pins 1-8 are bussed together.
	SPARE	
+	DC POWER	+ 5 VDC, 300 mA source (combined rating with Control Output, if used).
	Digital Ground	The ground level from the analyzer's internal DC power supplies

### 3.3.1.6. CONNECTING THE CONTROL INPUTS

If you wish to use the analyzer to remotely activate the zero and span calibration modes, several digital control inputs are provided through a 10-pin connector labeled **CONTROL IN** on the analyzer's rear panel.

There are two methods for energizing the control inputs. The internal +5V available from the pin labeled "+" is the most convenient method (Figure 3-10, left). However, if full isolation is required, an external 5 VDC power supply should be used (Figure 3-10, right).

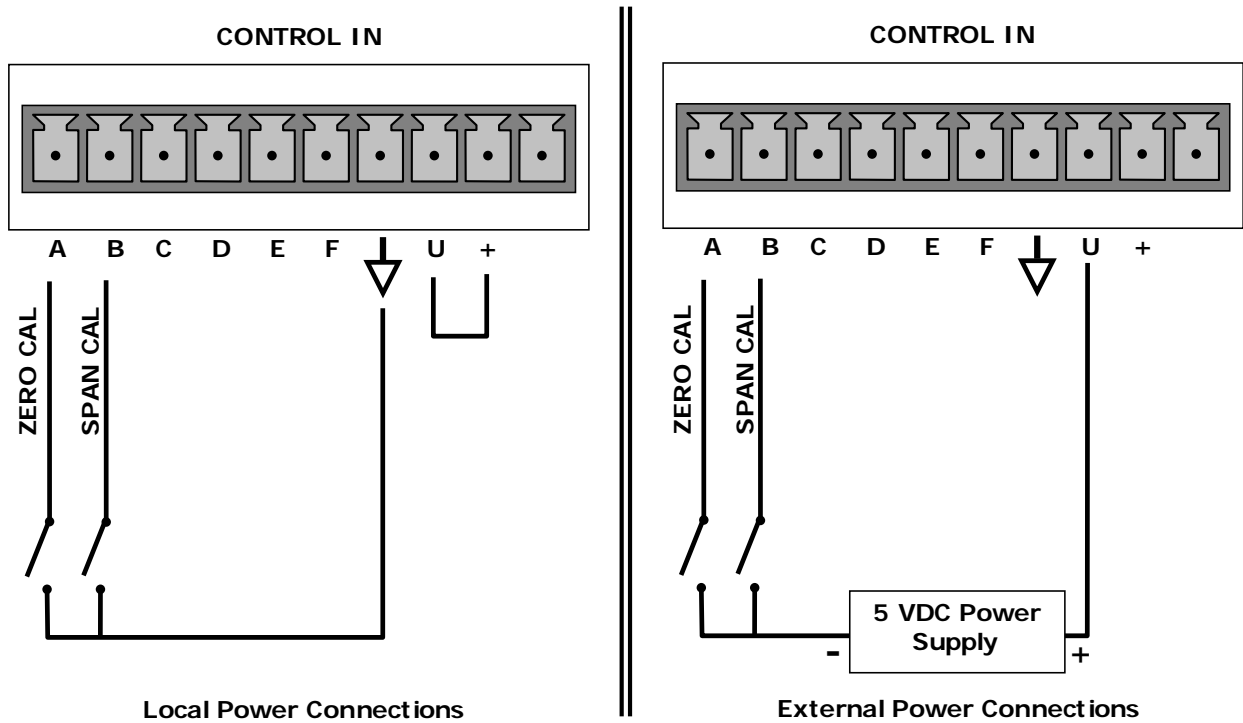


Figure 3-10: Control Input Connector

Table 3-8: Control Input Signals

Input #	Status Definition	ON Condition
A	<b>REMOTE ZERO CAL</b>	The analyzer is placed in Zero Calibration mode. The mode field of the display will read <b>ZERO CAL R.</b>
B	<b>REMOTE SPAN CAL</b>	The analyzer is placed in span calibration mode as part of performing a low span (midpoint) calibration. The mode field of the display will read <b>LO CAL R.</b>
C, D, E & F	SPARE	
⏚	Digital Ground	The ground level from the analyzer’s internal DC power supplies (same as chassis ground)
U	External Power input	Input pin for +5 VDC is required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the “U” pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

### 3.3.1.7. CONNECTING THE CONCENTRATION ALARM RELAY (OPTION 61)

The concentration alarm option is comprised of four (4) “dry contact” relays on the rear panel of the instrument. This relay option is different from and in addition to the “Contact Closures” that come standard on all Teledyne API instruments. Each relay has 3 pins: Normally Open (NO), Common (C) and Normally Closed (NC).

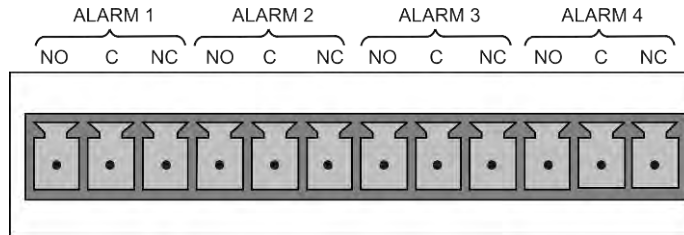


Figure 3-11: Concentration Alarm Relay

**Alarm 1** “System OK 2”

**Alarm 2** “Conc 1”

**Alarm 3** “Conc 2”

**Alarm 4** “Range Bit”

#### “ALARM 1” RELAY

Alarm 1, which is “System OK 2” (system OK 1 is the status bit), is in the energized state when the instrument is “OK” and there are no warnings. If there is a warning active or if the instrument is put into the “DIAG” mode, Alarm 1 will change states. This alarm has “reverse logic” meaning that if you put a meter across the Common and Normally Closed pins on the connector, you will find that it is OPEN when the instrument is OK. This is so that if the instrument should turn off or lose power, it will change states and you can record this with a data logger or other recording device.

#### “ALARM 2” RELAY & “ALARM 3” RELAY

Alarm 2 relay is associated with the “Concentration Alarm 1” set point in the software; Alarm 3 relay is associated with the “Concentration Alarm 2” set point in the software.

**Alarm 2 Relay** SO<sub>2</sub> Alarm 1 = xxx PPM

**Alarm 3 Relay** SO<sub>2</sub> Alarm 2 = xxx PPM

**Alarm 2 Relay** SO<sub>2</sub> Alarm 1 = xxx PPM

**Alarm 3 Relay** SO<sub>2</sub> Alarm 2 = xxx PPM

Alarm 2 relay will be turned on any time the concentration value exceeds the set-point, and will return to its normal state when the concentration value returns below the concentration set-point.

Even though the relay on the rear panel is a non-latching alarm and resets when the concentration goes back below the alarm set point, the warning on the front panel of the instrument will remain latched until it is cleared. You can clear the warning on the front panel either manually by pressing the CLR button on the front panel touch-screen or remotely through the serial port.

It is possible to configure the alarms to have two alarm levels for each concentration.

**SO<sub>2</sub> Alarm 1 = 20 PPM**

**SO<sub>2</sub> Alarm 2 = 100 PPM**

**SO<sub>2</sub> Alarm 1 = 20 PPM**

**SO<sub>2</sub> Alarm 2 = 100 PPM**

In this example, SO<sub>2</sub> Alarm 1 and SO<sub>2</sub> Alarm 1 will both be associated with the “Alarm 2” relay on the rear panel. This allows you to have multiple alarm levels for individual concentrations.

A more likely configuration for this would be to put one concentration on the “Alarm 1” relay and the other concentration on the “Alarm 2” relay.

**SO<sub>2</sub> Alarm 1 = 20 PPM**

**SO<sub>2</sub> Alarm 2 = Disabled**

**SO<sub>2</sub> Alarm 1 = Disabled**

**SO<sub>2</sub> Alarm 2 = 100 PPM**

#### **“ALARM 4” RELAY**

This relay is connected to the “range bit”. If the instrument is configured for “Auto Range” and the reading goes up into the high range, it will turn this relay on.

### **3.3.1.8. CONNECTING THE COMMUNICATIONS INTERFACES**

Available remote communications interfaces are: **Ethernet**, **USB**, **RS-232**, **RS-232 Multidrop** and **RS-485**. Use appropriate cables, and configure each type of communication method through the SETUP>COMM menu, Section 6. Although Ethernet is DHCP-enabled by default, it can also be configured manually (Section 6.5.1) to set up a static IP address, which is the recommended setting when operating the instrument via Ethernet.

#### **ETHERNET CONNECTION**

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer’s rear panel Ethernet interface connector to an Ethernet port. Please refer to Section 6.5 for a description of the default configuration and setup instructions.

**Configuration:** Section 6.5

- manual configuration: Section 6.5.1
- automatic configuration (default): Section 6.5.2

## USB CONNECTION

For direct communication between the analyzer and a PC, connect a USB cable between the analyzer rear panel and desktop or laptop USB ports, and ensure that their baud rates match (Section 6.2.2).

### Note

---

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

---

**Configuration:** Section 6.5.3

## RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A, Section 1.4), as applicable, from the analyzer's rear panel RS-232 port to the device. Adjust the DCE-DTE switch (Figure 3-4) to select DTE or DCE as appropriate.

**Configuration:** Sections 5.7 and 6.3

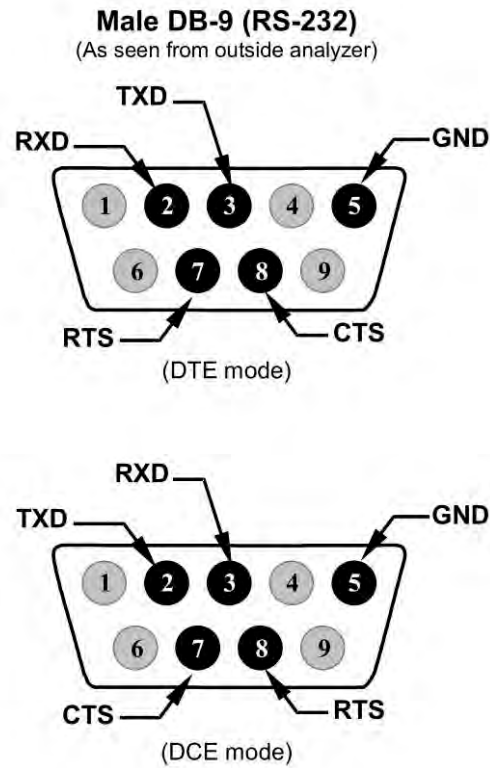
### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

**Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 3-12) before using.**

---

**RS-232 COM PORT CONNECTOR PIN-OUTS**

**Figure 3-12: Rear Panel Connector Pin-Outs for RS-232 Mode**

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 3-13).

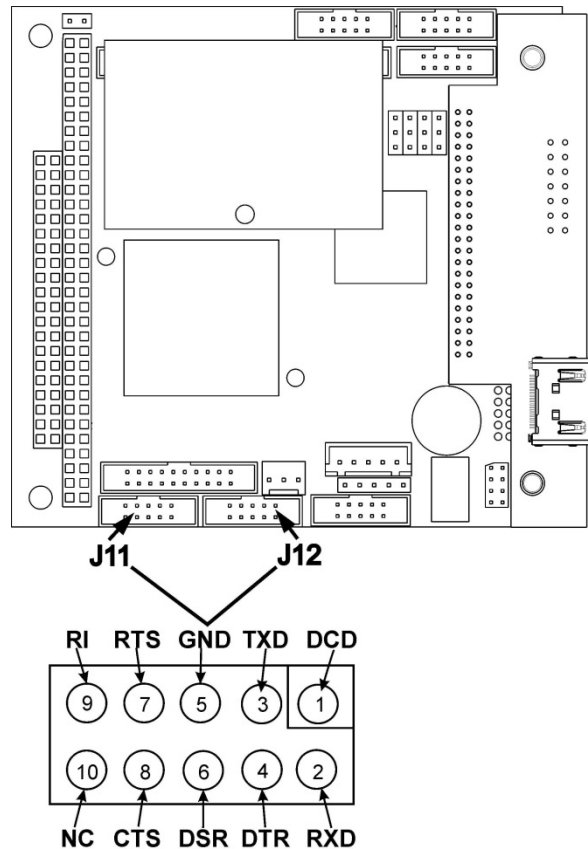


Figure 3-13: Default Pin Assignments for CPU Com Port Connector (RS-232)

### RS-232 COM PORT DEFAULT SETTINGS

As received from the factory, the analyzer is set up to emulate a DCE (Section 6.1) or modem, with Pin 3 of the DB-9 connector designated for receiving data and Pin 2 designated for sending data.

**RS-232:** RS-232 (fixed) DB-9 male connector

- Baud rate: 115200 bits per second (baud)
- Data Bits: 8 data bits with 1 stop bit
- Parity: None

**COM2:** RS-232 (configurable to RS 485), DB-9 female connector.

- Baud rate: 19200 bits per second (baud).
- Data Bits: 8 data bits with 1 stop bit.
- Parity: None.

**Configuration:** Section 6.3



## RS-232 MULTIDROP (OPTION 62) CONNECTION

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

### Note

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

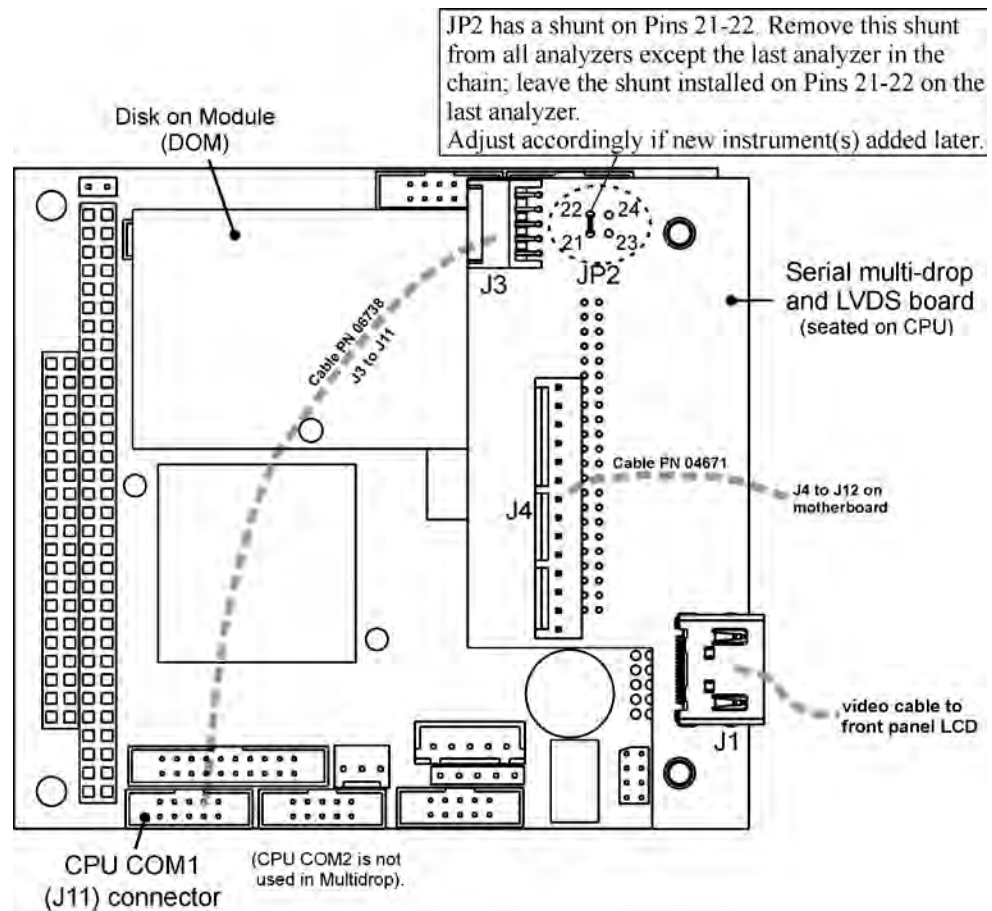
### ATTENTION

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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

In each instrument with the Multidrop option there is a shunt that jumpers two pins on the serial Multidrop and LVDS printed circuit assembly (PCA), as shown in Figure 3-14. This shunt must be removed from all instruments except that designated as last in the multidrop chain, which must remain terminated. This requires powering off and opening each instrument and making the following adjustments:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the multidrop/LVDS PCA, which is seated on the CPU.
2. On the multidrop PCA's JP2 connector, remove the shunt that jumpers Pins 21 ↔ 22 as indicated in Figure 3-14. (Do this for all but the last instrument in the chain where the shunt should remain at Pins 21 ↔ 22).
3. Check that the following cable connections are made in *all* instruments (again refer to Figure 3-14):
  - J3 on the Multidrop/LVDS PCA to the CPU's COM1 connector  
(Note that the CPU's COM2 connector is not used in Multidrop)
  - J4 on the Multidrop/LVDS PCA to J12 on the motherboard
  - J1 on the Multidrop/LVDS PCS to the front panel LCD



**Figure 3-14: Jumper and Cables for Multidrop Mode**

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

4. Close the instrument.
5. Referring to Figure 3-15 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.
6. On the rear panel of each analyzer, adjust the DCE DTE switch so that the green and the red LEDs (RX and TX) of the COM1 connector (labeled RS232) are both lit. (Ensure you are using the correct RS-232 cables internally wired specifically for RS-232 communication; see Section 3.3.1.8 under "RS-232 Connection".
7. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each (Section 5.7.1).
  - a. In the SETUP Mode menu go to SETUP>MORE>COMM>ID. The default ID is typically the model number or "0".

- b. To change the identification number, press the button below the digit to be changed.
  - c. Press/select ENTER to accept the new ID for that instrument.
8. Next, in the SETUP>MORE>COMM>COM1 menu (do not use the COM2 menu for multidrop), edit the COM1 MODE parameter as follows: press/select EDIT and set only QUIET MODE, COMPUTER MODE, and MULTIDROP MODE to ON. Do not change any other settings.
  9. Press/select ENTER to accept the changed settings, and ensure that COM1 MODE now shows 35.
  10. Press/select SET> to go to the COM1 BAUD RATE menu and ensure it reads the same for all instruments (edit as needed so that all instruments are set at the same baud rate).

**Note** The (communication) Host instrument can address only one instrument at a time, each by its unique ID (see step 7 above).

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

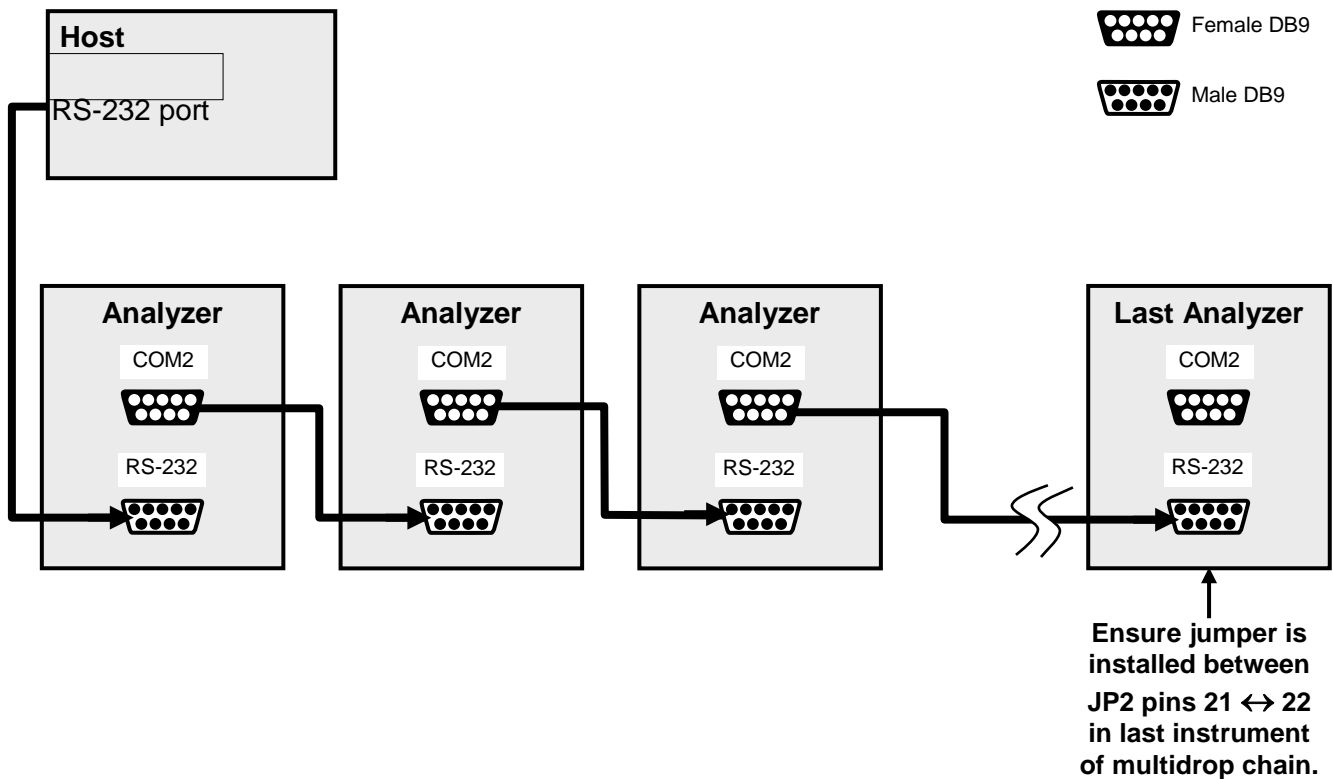


Figure 3-15: RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

### RS-485 CONNECTION (OPTION)

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

### 3.3.2. PNEUMATIC CONNECTIONS

This section provides not only pneumatic connection information, but also important information about the gases required for accurate calibration (Section 3.3.2.11); it also illustrates the pneumatic layouts for the analyzer in its basic configuration and with options.

Before making the pneumatic connections, carefully note the following cautionary and additional messages:



**CAUTION  
GENERAL SAFETY HAZARD  
SULFUR DIOXIDE (SO<sub>2</sub>) IS A TOXIC GAS.**

**DO NOT vent calibration gas and sample gas into enclosed areas. Obtain a Material Safety Data Sheet (MSDS) for this material. Read and rigorously follow the safety guidelines described there.**



**CAUTION  
GENERAL SAFETY HAZARD**

**Sample and calibration gases should only come into contact with PTFE (Teflon) or glass tubes and fixtures.**

**They SHOULD NOT come in contact with brass or stainless steel fittings prior to the reaction cell.**

**The exhaust from the analyzer's internal pump MUST be vented outside the immediate area or shelter surrounding the instrument.**

**It is important to conform to all safety requirements regarding exposure to SO<sub>2</sub>.**

**ATTENTION****-----  
COULD DAMAGE INSTRUMENT AND VOID WARRANTY****Maximum Pressure:**

Ideally the maximum pressure of any gas at the sample inlet should equal ambient atmospheric pressure and should NEVER exceed 1.5 in-hg above ambient pressure.

**Venting Pressurized Gas:**

In applications where any gas (span gas, zero air supply, sample gas is) received from a pressurized manifold, a vent must be provided to equalize the gas with ambient atmospheric pressure before it enters the analyzer to ensure that the gases input do not exceed the maximum inlet pressure of the analyzer, as well as to prevent back diffusion and pressure effects. These vents should be:

- at least 0.2m long
- no more than 2m long
- vented outside the shelter or immediate area surrounding the instrument.

**Dust Plugs:**

Remove dust plugs from rear panel exhaust and supply line fittings before powering on/operating instrument. These plugs should be kept for reuse in the event of future storage or shipping to prevent debris from entering the pneumatics.

**-----****IMPORTANT****EPA Requirements:**

US EPA requirements state that zero air and span gases must be supplied at twice the instrument's specified gas flow rate. Therefore, the T100 zero and span gases should be supplied to their respective inlets in excess of 1300 cc<sup>3</sup>/min (650 cc<sup>3</sup>/min. x 2).

**-----****IMPORTANT****Leak Check:**

Run a leak check once the appropriate pneumatic connections have been made; check all pneumatic fittings for leaks using the procedures defined in Section 10.3.6.

**-----****CAUTION – GENERAL SAFETY HAZARD**

Gas flow through the analyzer must be maintained at all time for units with a permeation tube installed. Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.

Section 3.3.2.1 provides external pneumatic connection instructions, and Table 3-9 provides links to the location of various internal pneumatic layout illustrations.

**Table 3-9: Pneumatic Layout Reference**

Pneumatic Layout	Section
Basic	3.3.2.2
Zero/Span Valves	3.3.2.3
Internal Zero/Span (IZS)	3.3.2.4
Basic with O <sub>2</sub> Sensor	3.3.2.9
Basic with CO <sub>2</sub> Sensor	3.3.2.10

### 3.3.2.1. BASIC CONNECTIONS INCLUDING W/SPAN GAS AND W/GAS DILUTION CALIBRATOR

Refer to Figure 3-4 and Table 3-3 while making the pneumatic connections as follows:

<b>SAMPLE</b> inlet	Connect ¼" gas line not more than 2 m long, from sample gas source to this inlet.  When no zero/span/shutoff valve options, also connect line from calibration gas source to this inlet, but only when a calibration operation is actually being performed.
<b>EXHAUST</b> outlet	Connect exhaust line made of PTEF tubing; minimum O.D ¼", to this fitting. The exhaust line should be no longer than 10 meters, and should lead outside the shelter or immediate area surrounding the instrument.

Figure 3-16 and Figure 3-17 illustrate pneumatic connections for two of the possible basic configurations.

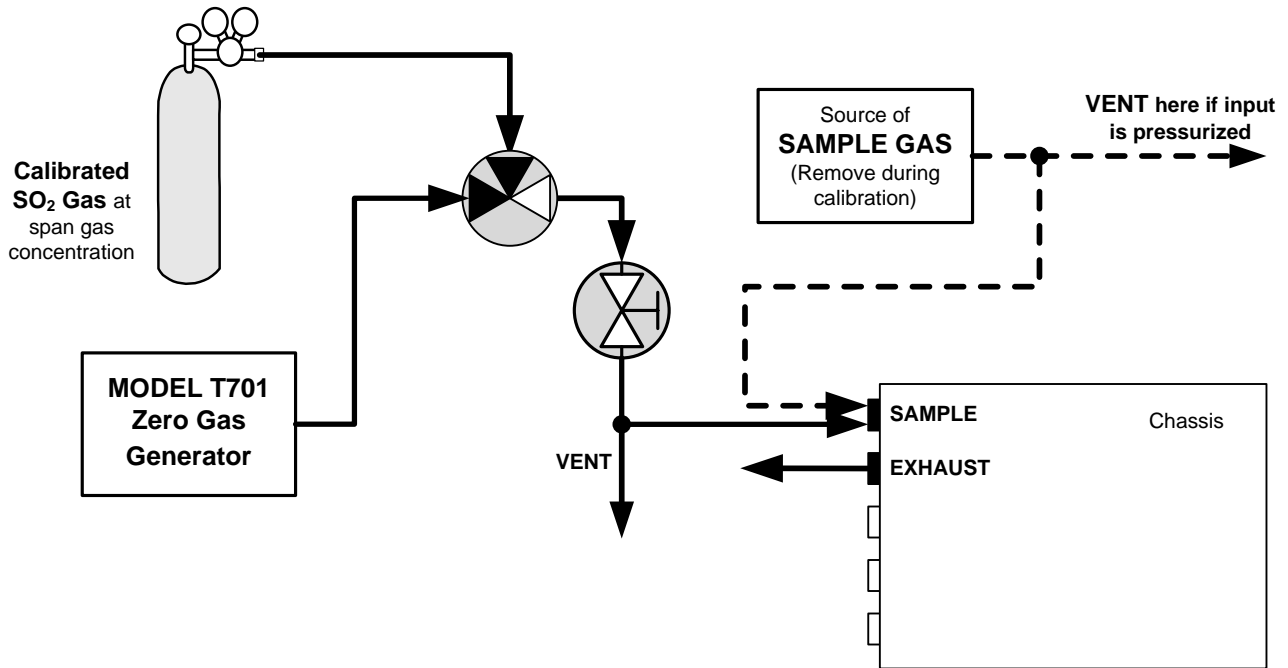


Figure 3-16: Pneumatic Connections—Basic Configuration—Using Bottled Span Gas

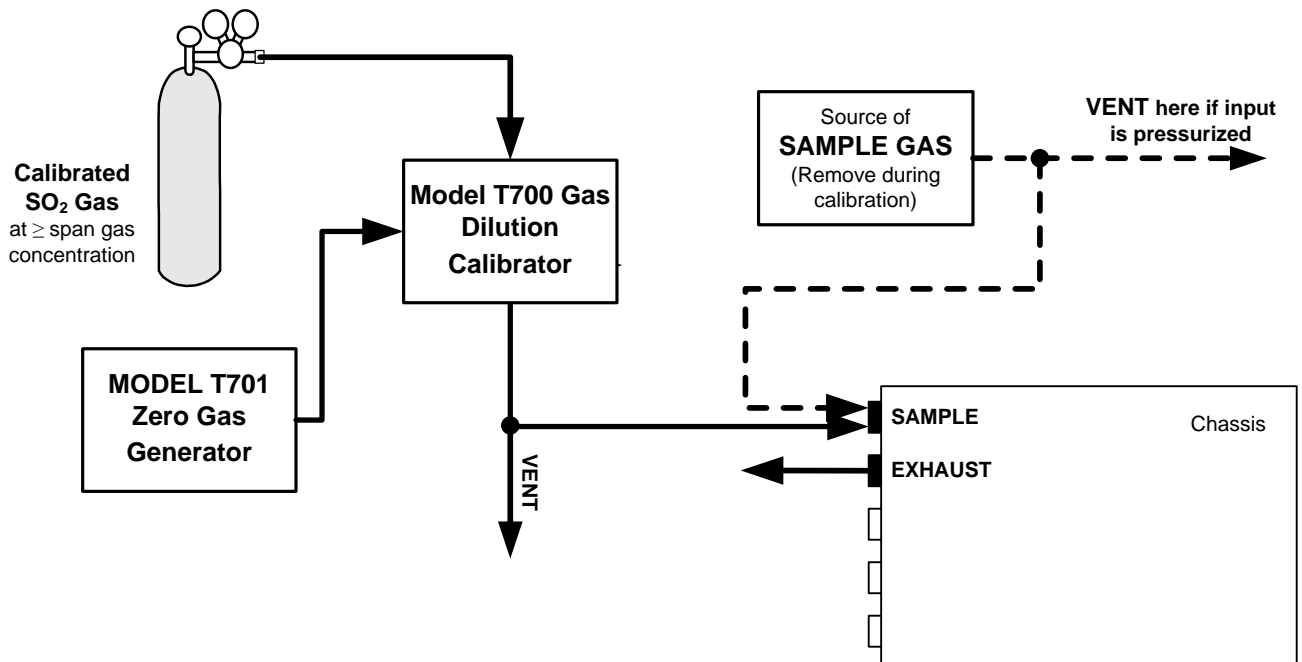


Figure 3-17: Pneumatic Connections—Basic Configuration—Using Gas Dilution Calibrator

3.3.2.2. PNEUMATIC LAYOUT FOR BASIC CONFIGURATION

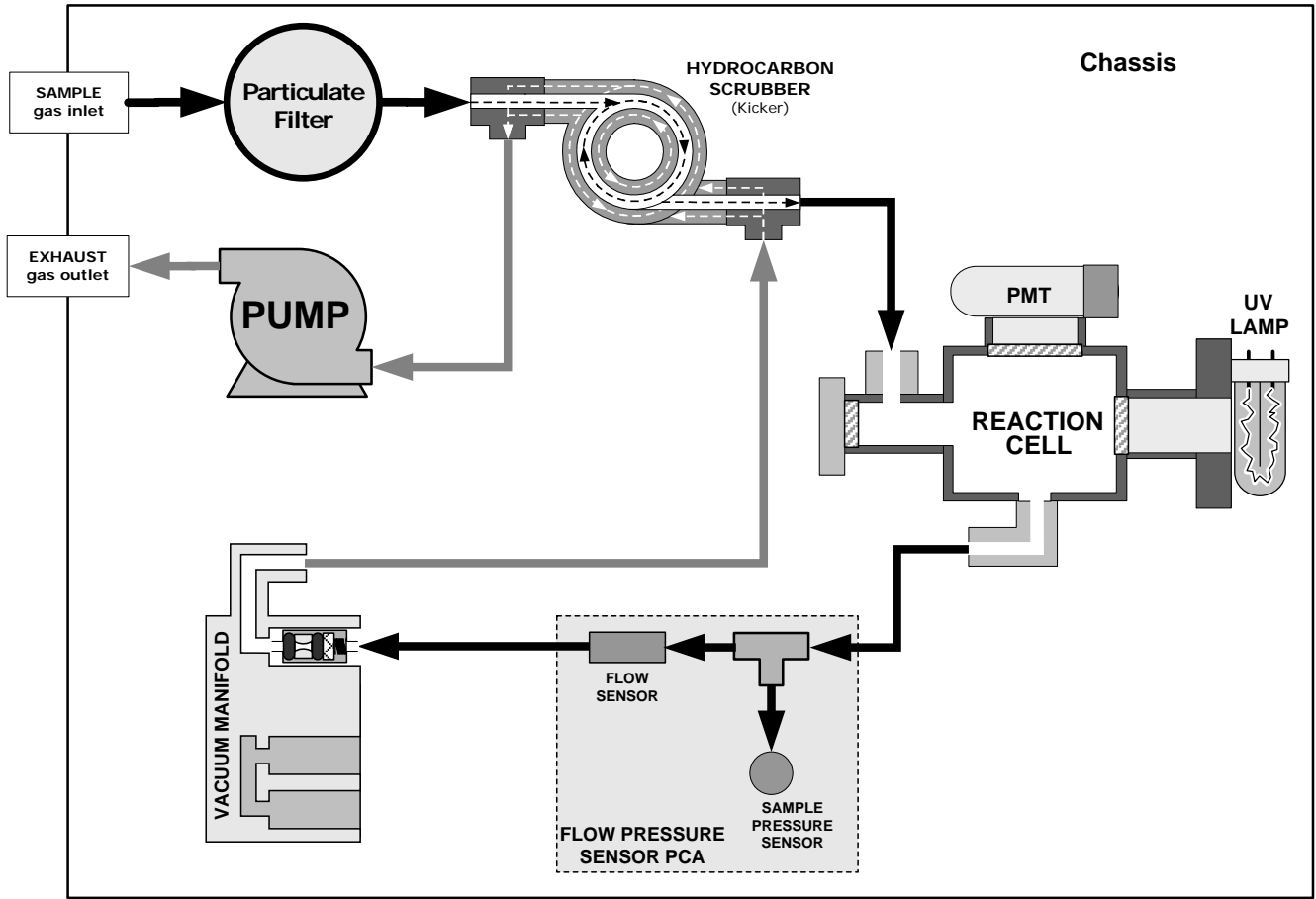


Figure 3-18: T100 Gas Flow, Basic Configuration



3.3.2.3. PNEUMATIC LAYOUT FOR ZERO/SPAN VALVES OPTION

Figure 3-19 shows the internal, pneumatic connections for a T100 with the zero/span valve option installed.

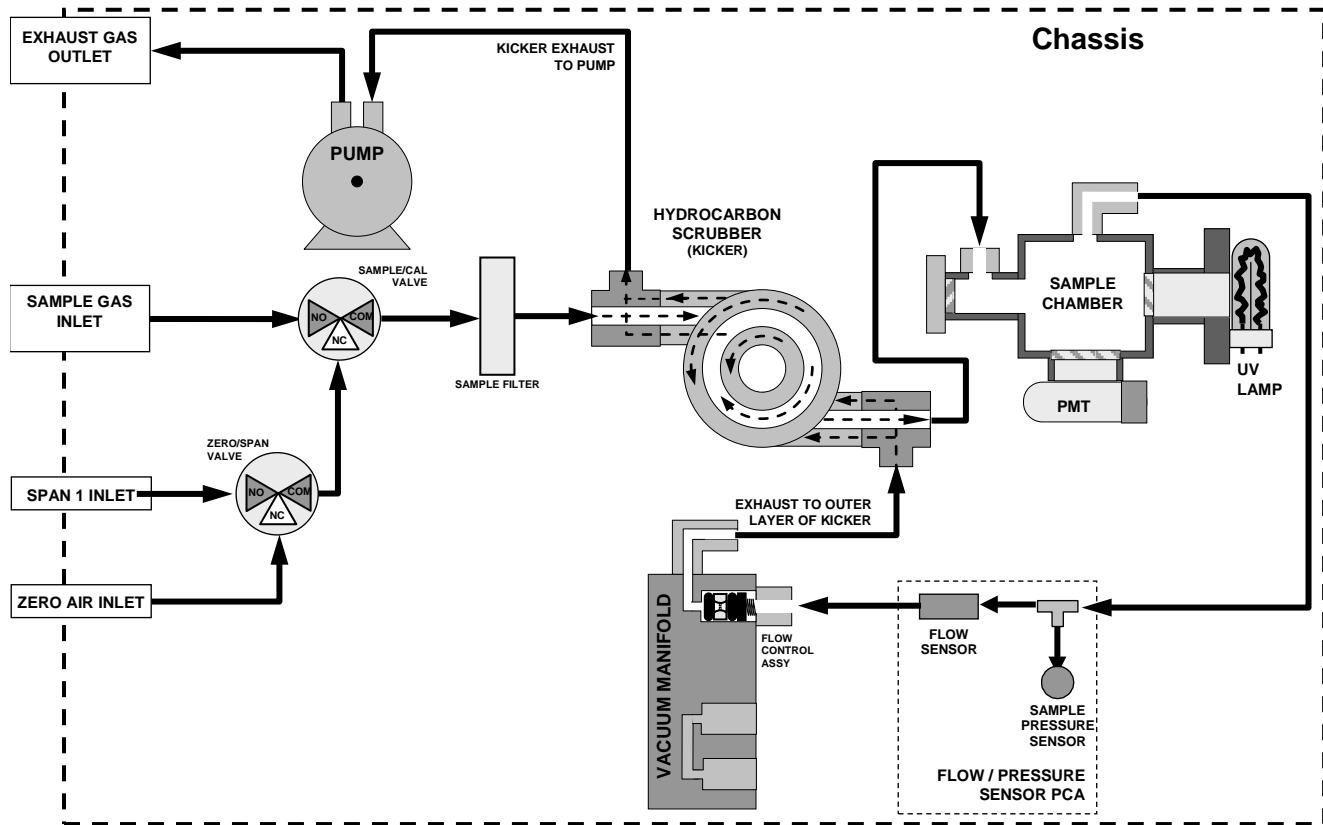


Figure 3-19: Pneumatic Layout with Zero/Span Valves Option

Table 3-10 describes the state of each valve during the analyzer’s various operational modes.

Table 3-10: Zero/Span and Sample/Cal Valve Operating States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to ZERO AIR inlet
ZERO CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to ZERO AIR inlet
SPAN CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to SPAN GAS inlet

The state of the zero/span valves can also be controlled by any of the following means:

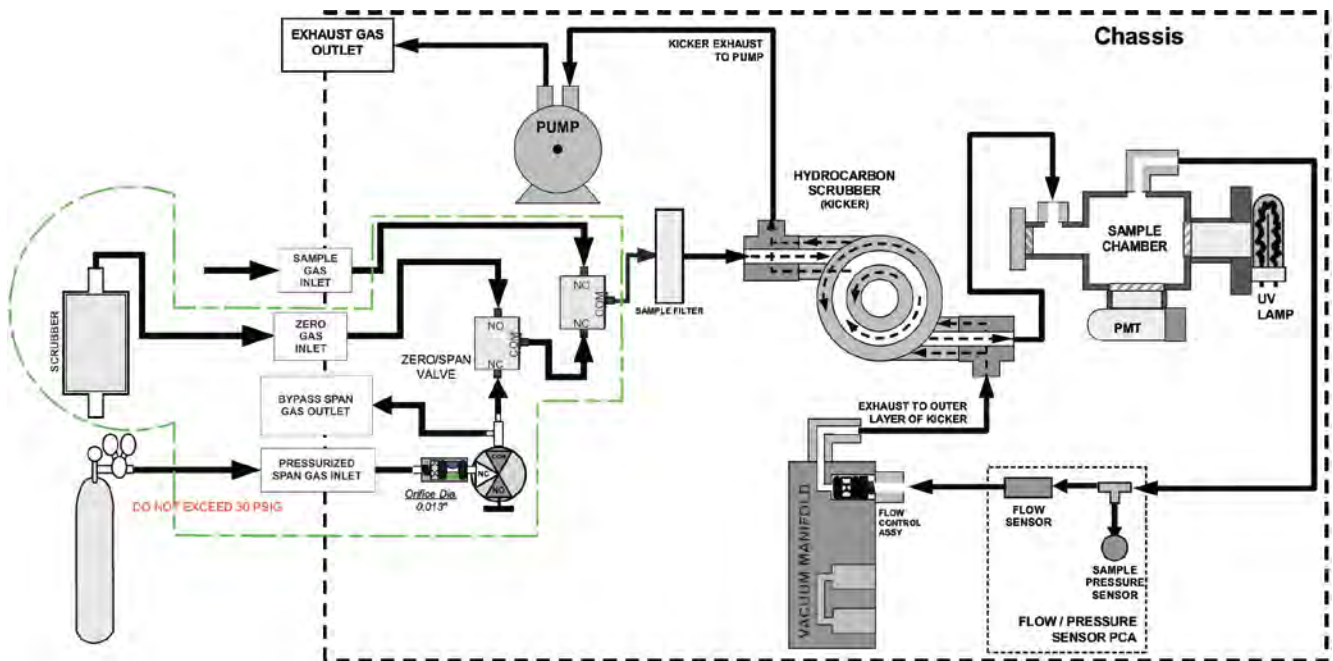
- manually from the analyzer’s front panel by using the **SIGNAL I/O** controls located within the **DIAG** Menu (refer to Section 5.9.1)
- by activating the instrument’s AutoCal feature (refer to Section 9.8)

- remotely by using the external digital control inputs (refer to Section 8.1.2 and Section 9.7.1)
- remotely through the RS-232/485 serial I/O ports (refer to Appendix A-6 for the appropriate commands)

Sources of zero and span gas must be capable of supplying at least 1.55 L/min. (maximum 2.5L/min). Both supply lines should be vented outside of the analyzer’s enclosure. In order to prevent back-diffusion and pressure effects, these vent lines should be between 2 and 10 meters in length.

**3.3.2.4. PNEUMATIC LAYOUT FOR PRESSURIZED SPAN/AMBIENT ZERO OPTION**

Figure 3-21 shows the internal, pneumatic connections for the analyzer with the pressurized span ambient zero option installed.



**Figure 3-20: Pneumatic Layout with Pressurized Span/Ambient Zero Option**

Table 3-11 describes the state of each valve during the analyzer’s various operational modes.

**Table 3-11: Zero/Span and Sample/Cal Valve Operating States**

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to ZERO AIR inlet
ZERO CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to ZERO AIR inlet
SPAN CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to SPAN GAS inlet
	Press Span	Open to SPAN GAS inlet

The state of the zero/span valves can also be controlled by any of the following means:

- manually from the analyzer's front panel by using the **SIGNAL I/O** controls located within the **DIAG** Menu (refer to Section 5.9.1)
- by activating the instrument's AutoCal feature (refer to Section 9.8)
- remotely by using the external digital control inputs (refer to Section 8.1.2 and Section 9.7.1)
- remotely through the RS-232/485 serial I/O ports (refer to Appendix A-6 for the appropriate commands)

Sources of zero and span gas must be capable of supplying at least 1.55 L/min. (maximum 2.5L/min). The supply line should be vented outside of the analyzer's enclosure. In order to prevent back-diffusion and pressure effects, these vent lines should be between 2 and 10 meters in length.

### 3.3.2.5. PNEUMATIC LAYOUT FOR INTERNAL ZERO/SPAN (IZS) GAS GENERATOR OPTION

Figure 3-21 shows the internal, pneumatic connections for the analyzer with the IZS option installed.

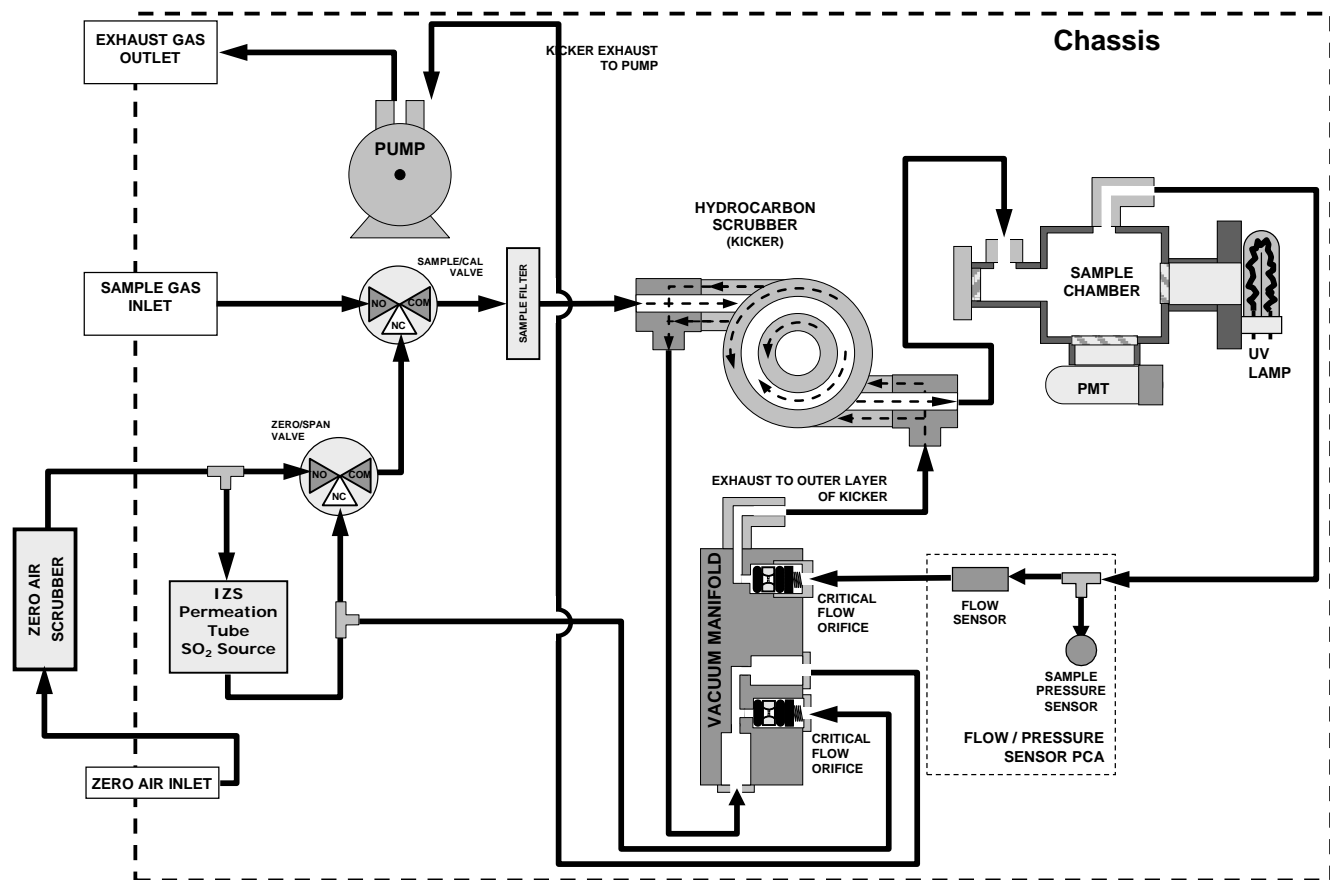


Figure 3-21: Pneumatic Layout with IZS Options

The internal zero air and span gas generator (IZS) option includes a heated enclosure (Section 3.3.2.6) for a permeation tube (permeation tube must be purchased separately; see Section 1.4, in SO<sub>2</sub> IZS Permeation Tubes option), an external scrubber (Section 3.3.2.8) for producing zero air and a set of valves for switching between the sample gas inlet and the output of the zero/span subsystem, functionally very similar to the valves included in the zero/span valve option.

Table 3-12 describes the operational state of the valves associated with the IZS option during the analyzer's various operating modes.

**Table 3-12: IZS Valve Operating States**

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to ZERO AIR inlet
ZERO CAL	Sample/Cal	Open to zero/span valve
	Zero/Span	Open to ZERO AIR inlet
SPAN CAL	Sample/Cal	Open to zero/span valve
	Zero/Span	Open to SPAN GAS inlet

The state of the IZS valves can also be controlled by any of the following means:

- Manually from the analyzer's front panel by using the **SIGNAL I/O** controls under the **DIAG** Menu (refer to Section 5.9.1),
- By activating the instrument's AutoCal feature (refer to Section 9.8),
- Remotely by using the external digital control inputs (refer to Section 8.1.2 and Section 9.7.1),
- Remotely through the RS-232/485 serial I/O ports (refer to Appendix A-6 for the applicable commands), or
- Remotely via Ethernet

#### Note

**The permeation tube is not included in the IZS Option and must be ordered separately. Refer to Section 1.4 for permeation tube options.**

#### 3.3.2.6. PERMEATION TUBE HEATER

In order to keep the permeation rate constant, the IZS enclosure is heated to a constant 50 C (10° above the maximum operating temperature of the instrument). The IZS heater is controlled by a precise PID (Proportional/Integral/Derivative) temperature control loop. A thermistor measures the actual temperature and reports it to the CPU for control feedback.

The IZS option includes an external zero air scrubber assembly that removes all SO<sub>2</sub> the zero air source. The scrubber is filled with activated charcoal.

### 3.3.2.7. SPAN GAS CONCENTRATION VARIATION

Span gas is created when zero air passes over a permeation tube containing liquid SO<sub>2</sub> under high pressure, which slowly permeates through a PTFE membrane into the surrounding air. The speed at which the SO<sub>2</sub> permeates the membrane is called the effusion rate. The concentration of the span gas is determined by three factors:

- Size of the membrane: The larger the area of the membrane, the more permeation occurs.
- Temperature of the SO<sub>2</sub>: Increasing the temperature of the increases the pressure inside the tube and therefore increases the effusion rate.
- Flow rate of the zero air: If the previous two variables are constant, the permeation rate of air into the zero air stream will be constant. Therefore, a lower flow rate of zero air produces higher concentrations of SO<sub>2</sub>. The T100 usually has a constant flow rate and a constant permeation rate; hence, variations in concentration can be achieved by changing the IZS temperature.

### 3.3.2.8. EXTERNAL ZERO AIR SCRUBBER

The IZS option includes an external zero air scrubber assembly that removes all SO<sub>2</sub> from the zero air source. The scrubber is filled with activated charcoal.

3.3.2.9. PNEUMATIC LAYOUT WITH O<sub>2</sub> SENSOR OPTION

Figure 3-22 shows the internal, pneumatic connections for the analyzer with the oxygen (O<sub>2</sub>) sensor option installed. Pneumatically, the O<sub>2</sub> sensor draws a flow of 80 cm<sup>3</sup>/min in addition to the normal sample flow rate. It is separately controlled with its own critical flow orifice.

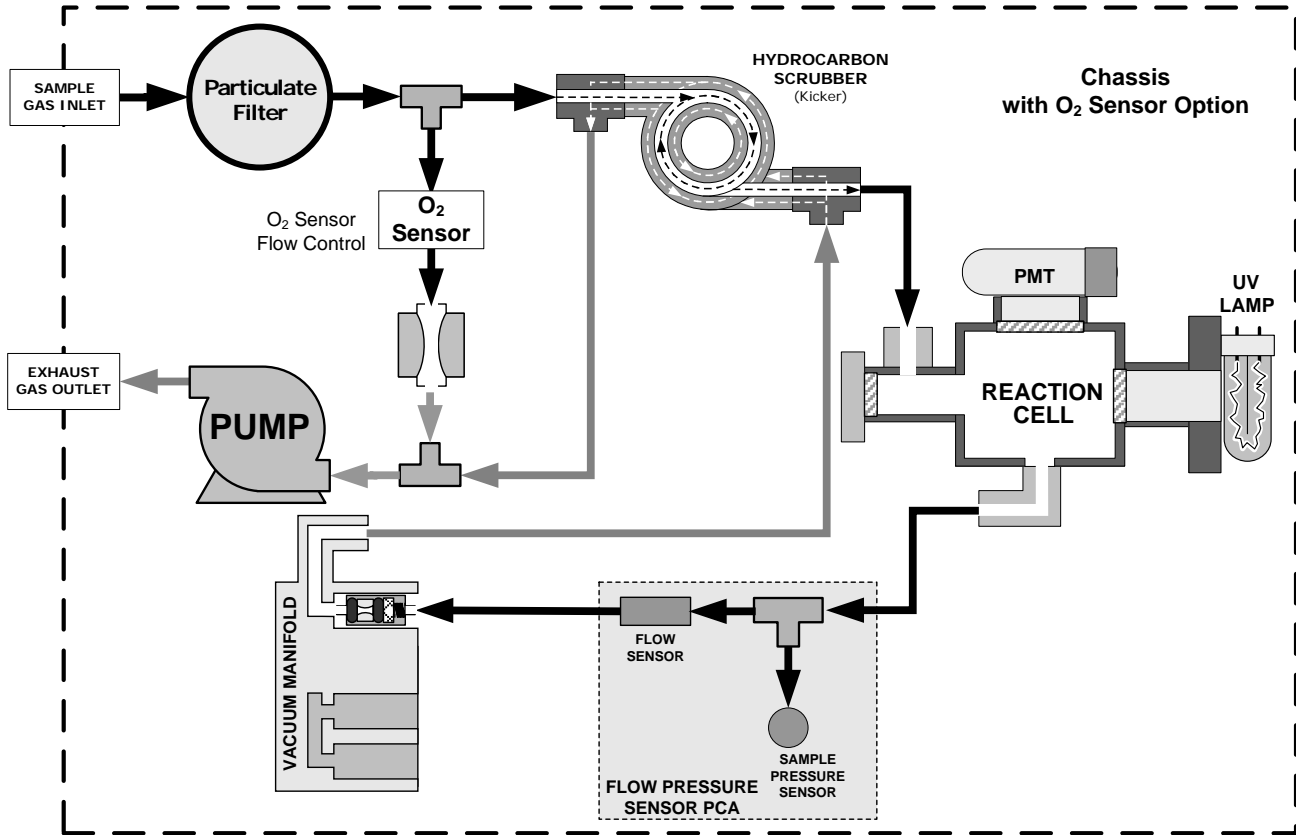


Figure 3-22: Pneumatic Layout with O<sub>2</sub> Sensor

### 3.3.2.10. PNEUMATIC LAYOUT WITH CO<sub>2</sub> SENSOR OPTION

Figure 3-23 shows the internal, pneumatic connections for the analyzer with the carbon dioxide (CO<sub>2</sub>) sensor option installed. Pneumatically, the CO<sub>2</sub> sensor is placed in line with the sample gas line between the particulate filter and the analyzer's sample chamber. It does not alter the gas flow rate of the sample through the analyzer.

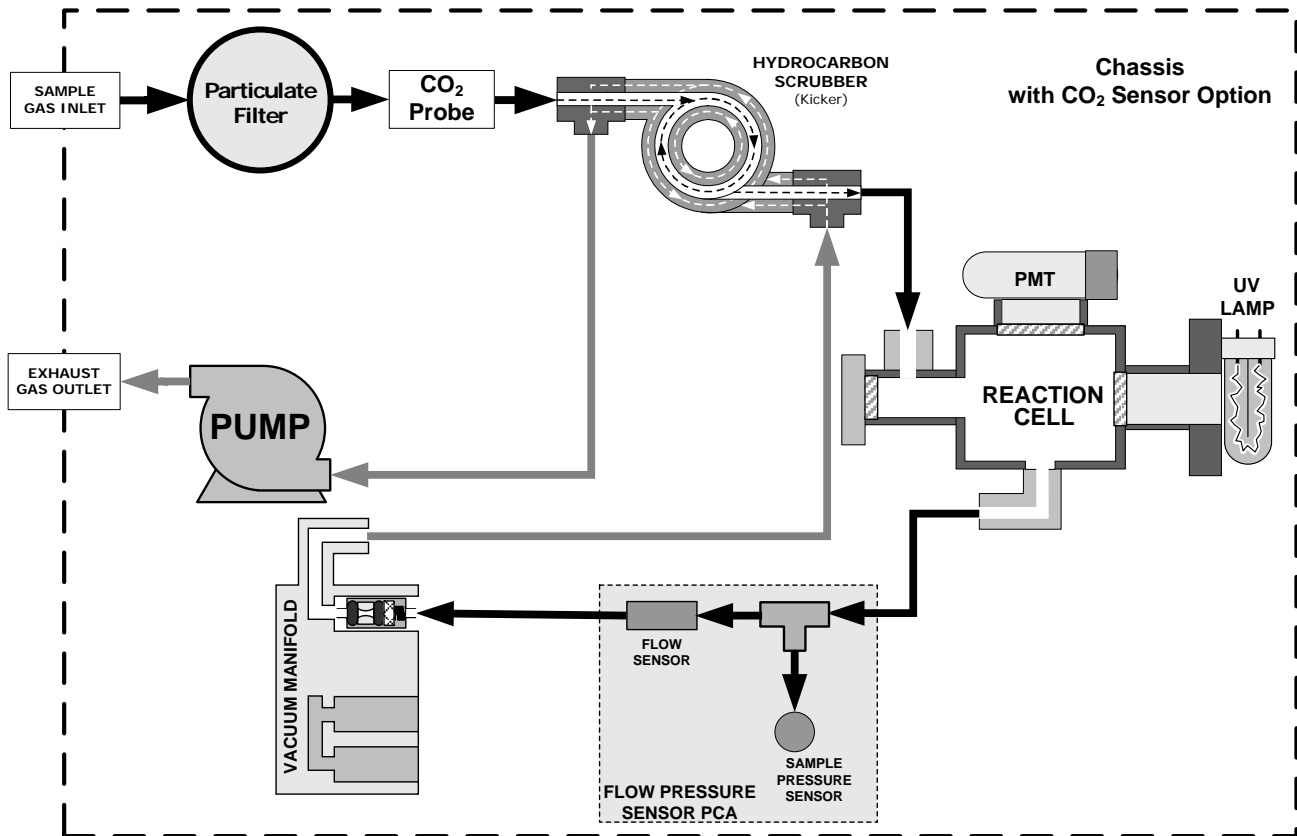


Figure 3-23: Pneumatic Layout with CO<sub>2</sub> Sensor

### 3.3.2.11. ABOUT ZERO AIR AND CALIBRATION (SPAN) GASES

Zero air and span gas are required for accurate calibration.

#### ZERO AIR

Zero air is a gas that is similar in chemical composition to the earth's atmosphere but without the gas being measured by the analyzer, in this case SO<sub>2</sub>. If your analyzer is equipped with an Internal Zero Span (IZS) or an external zero air scrubber option, it is capable of creating zero air.

For analyzers without an IZS or external zero air scrubber option, a zero air generator such as the Teledyne API Model 701 can be used (Figure 3-16).

## CALIBRATION (SPAN) GAS

Calibration gas is specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range. In this case, SO<sub>2</sub> measurements made with the Teledyne API T100 UV Fluorescence SO<sub>2</sub> Analyzer, it is recommended that you use a span gas with a SO<sub>2</sub> concentration equal to 80% of the measurement range for your application.

EXAMPLE: If the application is to measure between 0 ppm and 500 ppb, an appropriate span gas concentration would be 450 ppb SO<sub>2</sub>.

Cylinders of calibrated SO<sub>2</sub> gas traceable to NIST-Standard Reference Material specifications (also referred to as SRM's or EPA protocol calibration gases) are commercially available. Table 3-13 lists specific NIST-SRM reference numbers for various concentrations of SO<sub>2</sub>.

**Table 3-13: NIST-SRM's Available for Traceability of SO<sub>2</sub> Calibration Gases**

NIST-SRM	Type	Nominal Concentration
1693a	Sulfur dioxide in N <sub>2</sub>	50 ppm
1694a	Sulfur dioxide in N <sub>2</sub>	100 pp
1661a	Sulfur dioxide in N <sub>2</sub>	500 ppm
2659a <sup>1</sup>	O <sub>2</sub> in N <sub>2</sub>	21% by weight
2626a	CO <sub>2</sub> in N <sub>2</sub>	4% by weight
2745 <sup>2</sup>	CO <sub>2</sub> in N <sub>2</sub>	16% by weight
<sup>1</sup> Used to calibrate optional O <sub>2</sub> sensor.		
<sup>2</sup> Used to calibrate optional CO <sub>2</sub> sensor.		

## SPAN GAS FOR MULTIPOINT CALIBRATION

Some applications, such as EPA monitoring, require a multipoint calibration procedure where span gases of different concentrations are needed. We recommend using a bottle of calibrated SO<sub>2</sub> gas of higher concentration in conjunction with a gas dilution calibrator such as a Teledyne API Model T700 (Figure 3-17). This type of calibrator precisely mixes a high concentration gas with zero air (both supplied externally) to accurately produce span gas of the correct concentration. Linearity profiles can be automated with this model and run unattended over night.

If a dynamic dilution system is used to dilute high concentration gas standards to low, ambient concentrations, ensure that the SO<sub>2</sub> concentration of the reference gas matches the dilution range of the calibrator.

Choose the SO<sub>2</sub> gas concentration so that the dynamic dilution system operates in its mid-range and not at the extremes of its dilution capabilities.

EXAMPLE:

- A dilution calibrator with 10-10000 dilution ratio will not be able to accurately dilute a 5000 ppm SO<sub>2</sub> gas to a final concentration of 500 ppb, as this would operate at the very extreme dilution setting.
- A 100 ppm SO<sub>2</sub> gas in nitrogen is much more suitable to calibrate the T100 analyzer (dilution ratio of 222, in the mid-range of the system's capabilities).



### 3.4. STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION

If you are unfamiliar with the T100 principles of operation, we recommend that you read Section 12. For information on navigating the analyzer’s software menus, refer to the menu trees provided in Appendix A.

CAUTION - GENERAL SAFETY HAZARD

**Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material whenever working with the UV Lamp. (Generic plastic glasses are not adequate).**

#### 3.4.1. STARTUP

After the electrical and pneumatic connections are made, run an initial functional check. Turn on the instrument. The pump and exhaust fan should start immediately. The display will show a momentary splash screen of the Teledyne API logo and other information during the initialization process while the CPU loads the operating system, the firmware and the configuration data.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring the gas. However, there is an approximately one hour warm-up period before reliable gas measurements can be taken. During the warm-up period, the front panel display may show messages in the Parameters field.

#### 3.4.2. WARNING MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the analyzer’s warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 60 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 11.1.1.

To view and clear warning messages, press:

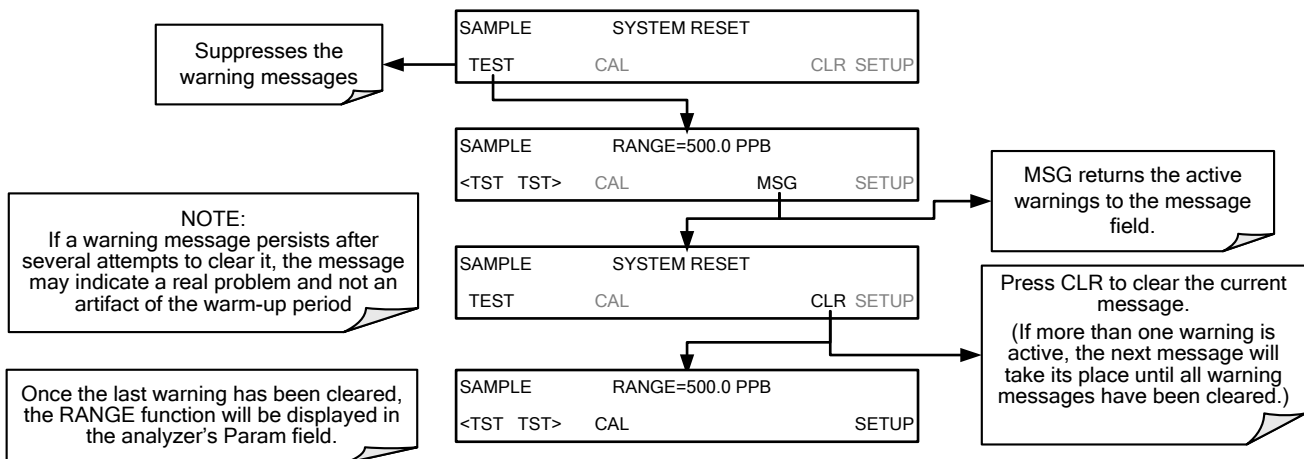


Figure 3-24: Warning Messages

Table 3-14 lists brief descriptions of the warning messages that may occur during start up for T100 analyzers with no options installed.

**Table 3-14: Possible Startup Warning Messages – T100 Analyzers w/o Options**

Message	Meaning
<b>ANALOG CAL WARNING</b>	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
<b>BOX TEMP WARNING</b>	The temperature inside the T100 chassis is outside the specified limits.
<b>CANNOT DYN SPAN<sup>2</sup></b>	Remote span calibration failed while the dynamic span feature was set to turned on.
<b>CANNOT DYN ZERO<sup>3</sup></b>	Remote zero calibration failed while the dynamic zero feature was set to turned on.
<b>CONFIG INITIALIZED</b>	Configuration was reset to factory defaults or was erased.
<b>DARK CAL WARNING</b>	Dark offset above limit specified indicating that too much stray light is present in the sample chamber.
<b>DATA INITIALIZED</b>	DAS data storage was erased.
<b>HVPS WARNING</b>	High voltage power supply for the PMT is outside of specified limits.
<b>PMT DET WARNING</b>	PMT detector output is outside of operational limits.
<b>PMT TEMP WARNING</b>	PMT temperature is outside of specified limits.
<b>RCELL TEMP WARNING</b>	Sample chamber temperature is outside of specified limits.
<b>REAR BOARD NOT DET</b>	CPU unable to communicate with motherboard.
<b>RELAY BOARD WARN</b>	CPU is unable to communicate with the relay PCA.
<b>SAMPLE FLOW WARN</b>	The flow rate of the sample gas is outside the specified limits.
<b>SAMPLE PRESS WARN</b>	Sample gas pressure outside of operational parameters.
<b>SYSTEM RESET<sup>1</sup></b>	The computer was rebooted.
<b>UV LAMP WARNING</b>	The UV lamp intensity measured by the reference detector reading too low or too high.
<sup>1</sup> Clears 45 minutes after power up. <sup>2</sup> Clears the next time successful zero calibration is performed. <sup>3</sup> Clears the next time successful span calibration is performed.	

Table 3-15 lists brief descriptions of the warning messages that may occur during start up for T100 analyzers with optional second gas options or alarms installed.

**Table 3-15: Possible Startup Warning Messages – T100 Analyzers with Options**

Message	Meaning
<b>O2 CELL TEMP WARN<sup>1</sup></b>	O <sub>2</sub> sensor cell temperature outside of warning limits.
<b>IZS TEMP WARNING<sup>2</sup></b>	On units with IZS options installed: The permeation tube temperature is outside of specified limits.
<b>O2 ALARM 1 WARN<sup>1, 4</sup></b>	O <sub>2</sub> Alarm limit #1 has been triggered. <sup>4</sup>
<b>O2 ALARM 2 WARN<sup>1, 4</sup></b>	O <sub>2</sub> Alarm limit #2 has been triggered. <sup>4</sup>
<b>CO2 ALARM 1 WARN<sup>3, 4</sup></b>	CO <sub>2</sub> Alarm limit #1 has been triggered. <sup>4</sup>
<b>CO2 ALARM 2 WARN<sup>3, 4</sup></b>	CO <sub>2</sub> Alarm limit #2 has been triggered. <sup>4</sup>
<b>SO2 ALARM1 WARN<sup>4</sup></b>	SO <sub>2</sub> Alarm limit #1 has been triggered. <sup>4</sup>
<b>SO2 ALARM2 WARN<sup>4</sup></b>	SO <sub>2</sub> Alarm limit #2 has been triggered. <sup>4</sup>
<sup>1</sup> Only appears when the optional O <sub>2</sub> sensor is installed. <sup>2</sup> Only appears when the optional internal zero span (IZS) option is installed. <sup>3</sup> Only appears when the optional CO <sub>2</sub> sensor is installed. <sup>4</sup> Only appears when the optional gas concentration alarms are installed	

### 3.4.3. FUNCTIONAL CHECKS

After the analyzer's components have warmed up for at least 60 minutes, verify that the software properly supports any hardware options that were installed.

For information on navigating through the analyzer's software menus, refer to the menu trees described in Appendix A.

Check to ensure that the analyzer is functioning within allowable operating parameters.

- Appendix C includes a list of test functions viewable from the analyzer's front panel as well as their expected values.
- These functions are also useful tools for diagnosing performance problems with your analyzer (refer to Section 11.1.2).
- The Final Test and Validation Data Sheet (P/N 04551) included in the shipment lists these values before the instrument left the factory.

To view the current values of these parameters press the following control button sequence on the analyzer's front panel. Remember until the unit has completed its warm up these parameters may not have stabilized.

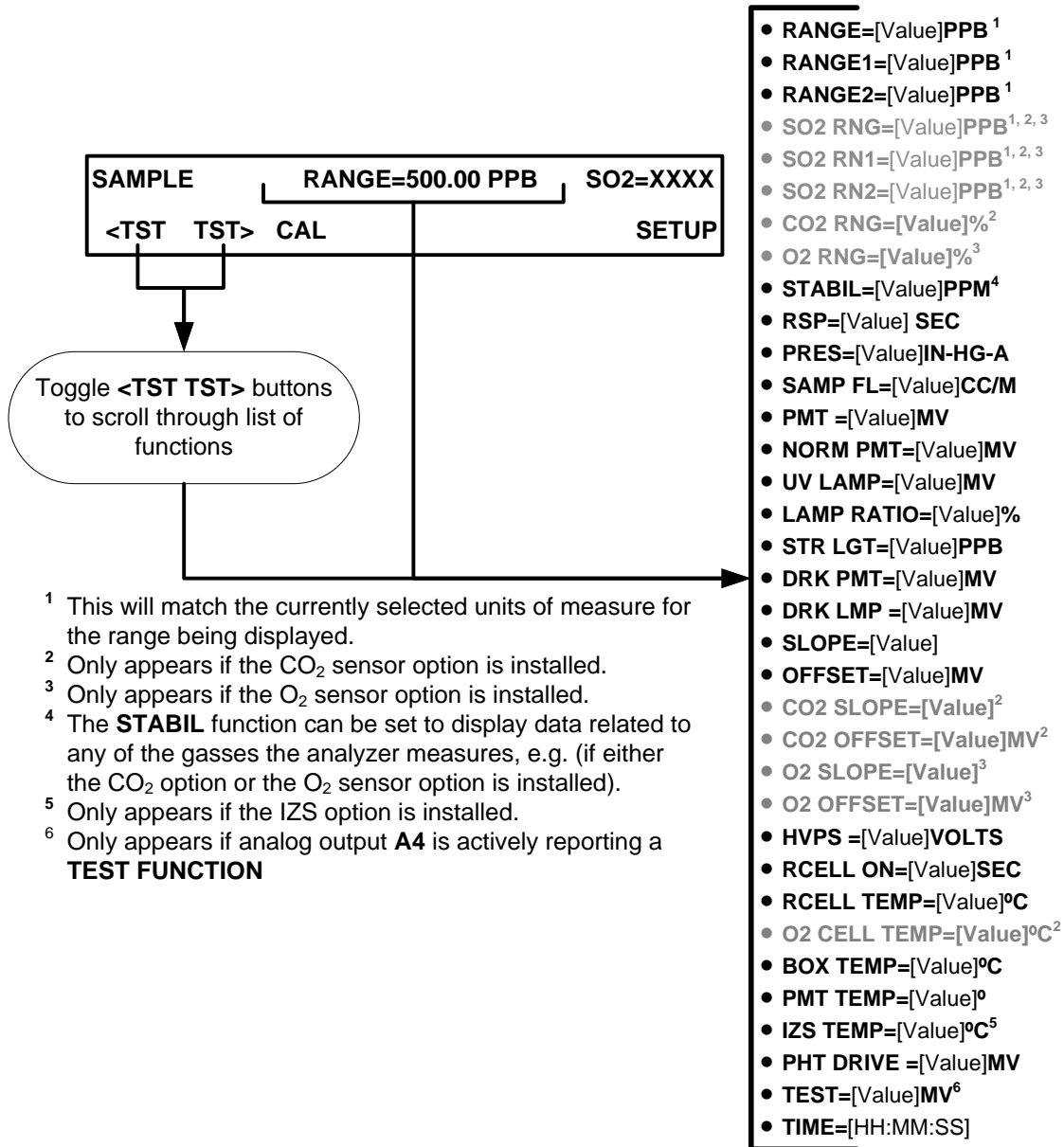


Figure 3-25: Functional Check

### 3.4.4. INITIAL CALIBRATION

To perform the following calibration you must have sources for zero air and span gas available for input into the sample port on the back of the analyzer. Refer to Section 3.3.2 for instructions for connecting these gas sources.

The initial calibration should be carried out using the same reporting range set-up as used during the analyzer's factory calibration. This will allow you to compare your calibration results to the factory calibration as listed on the *Final Test and Validation Data Sheet*, P/N 04551.

If both available DAS parameters for a specific gas type are being reported via the instrument's analog outputs (e.g. **CONC1** and **CONC2** when the **DUAL** range mode is activated), separate calibrations should be carried out for each parameter.

- Use the **LOW** button when calibrating for **CONC1** (equivalent to **RANGE1**).
- Use the **HIGH** button when calibrating for **CONC2** (equivalent to **RANGE2**).

Refer to the Configurable Analog Output Addendum, P/N 06270 for more information on the configurable analog output reporting ranges.

#### Note

**The following procedure assumes that the instrument does not have any of the available valve options installed. Refer to Section 9.4 for instructions for calibrating instruments possessing valve options**

#### Note

**The T100 analyzer has been tested for its ability to reject interference for most sources. See Section 12.1.9 for more information on this topic.**

#### 3.4.4.1. INITIAL CALIBRATION PROCEDURE FOR BASIC ANALYZERS (NO 2<sup>ND</sup> GAS OPTION)

The following procedure assumes that:

- The instrument DOES NOT have any of the available calibration valve or gas inlet options installed;
- Cal gas will be supplied through the SAMPLE gas inlet on the back of the analyzer (refer to Figure 3-4);
- The pneumatic setup matches that described in Section 3.3.2.

#### VERIFYING THE REPORTING RANGE SETTINGS

While it is possible to perform the following procedure with any range setting we recommend that you perform this initial checkout using following reporting range settings:

- Unit of Measure: PPB
- Analog Output Reporting Range: 500.0 ppb
- Mode Setting: SNGL

While these are the default settings for the T100 analyzer, it is recommended that you verify them before proceeding with the calibration procedure, by pressing:

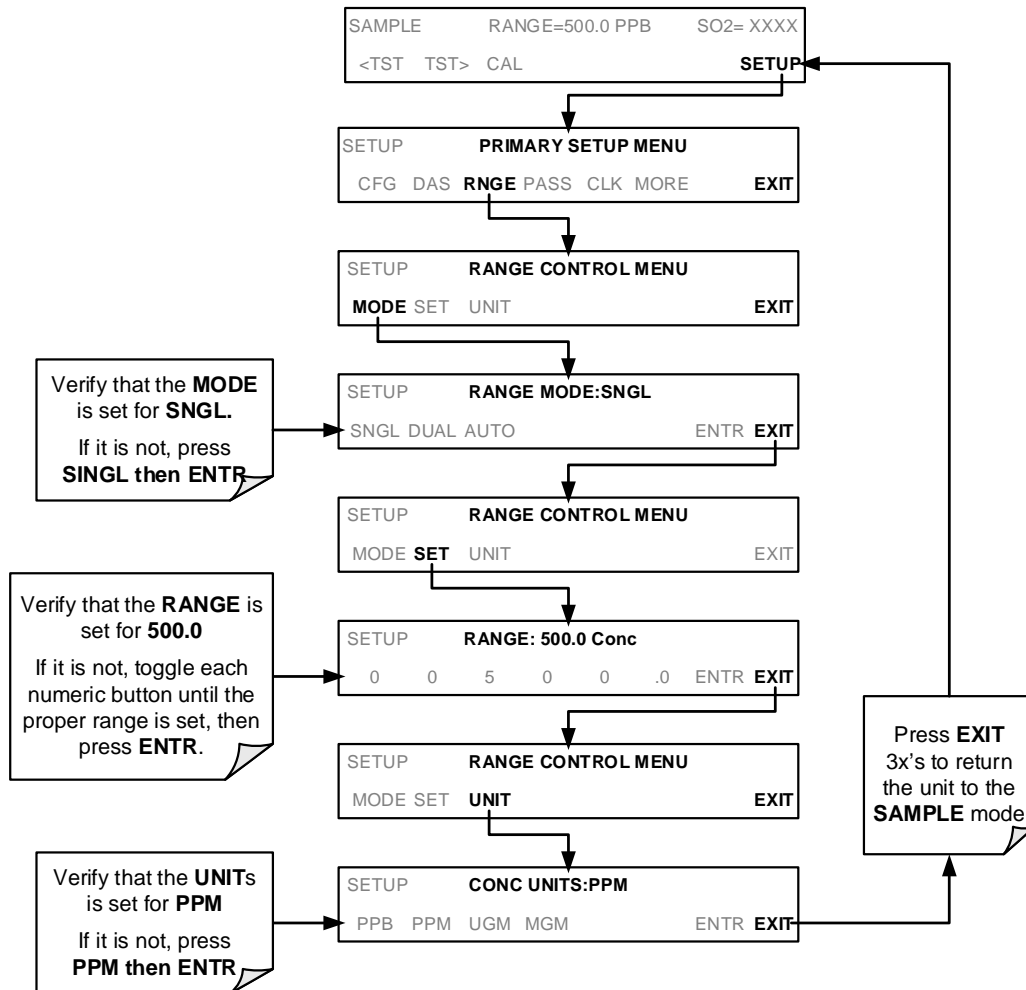


Figure 3-26: Reporting Range Verification

### DILUTION RATIO SETUP

If the dilution ratio option is enabled on your T100 and your application involves diluting the sample gas before it enters the analyzer, set the dilution ratio as follows:

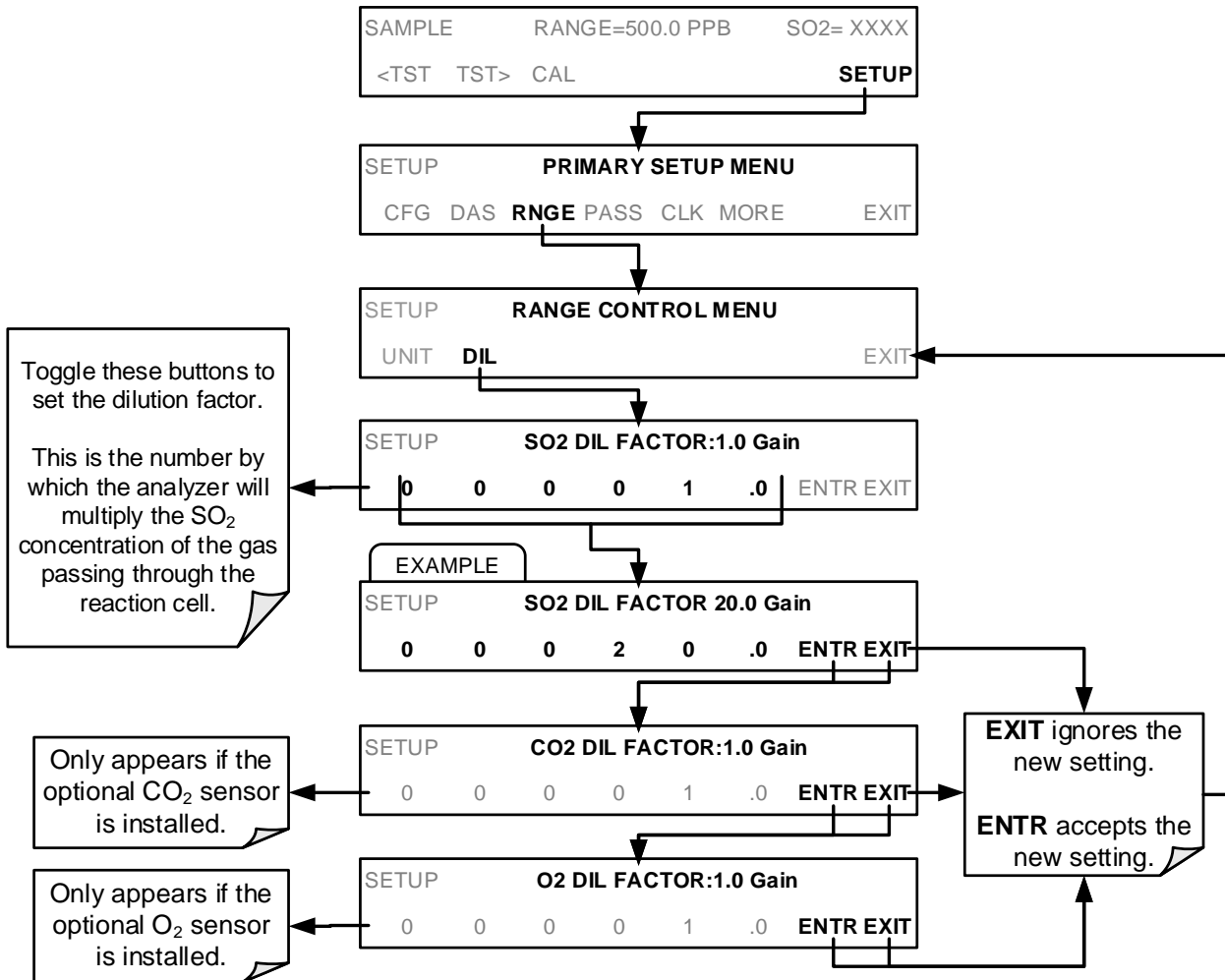


Figure 3-27: Dilution Ratio Setup

### SET SO<sub>2</sub> SPAN GAS CONCENTRATION

Set the expected SO<sub>2</sub> span gas concentration. This should be 80% of the concentration range for which the analyzer's analog output range is set.

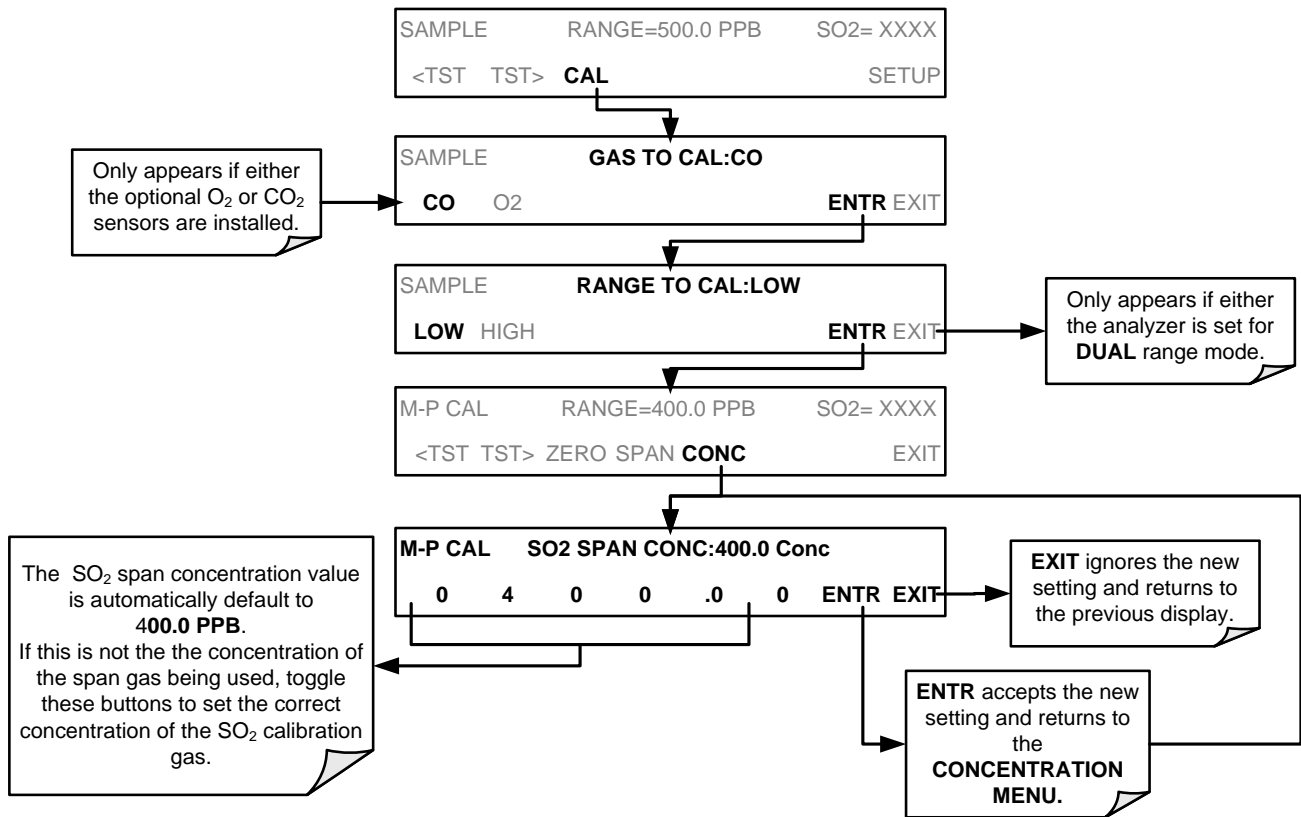


Figure 3-28: SO<sub>2</sub> Span Gas Setting



### ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure (see Section 9 for manual and automatic calibration procedures, including with valve options), press:

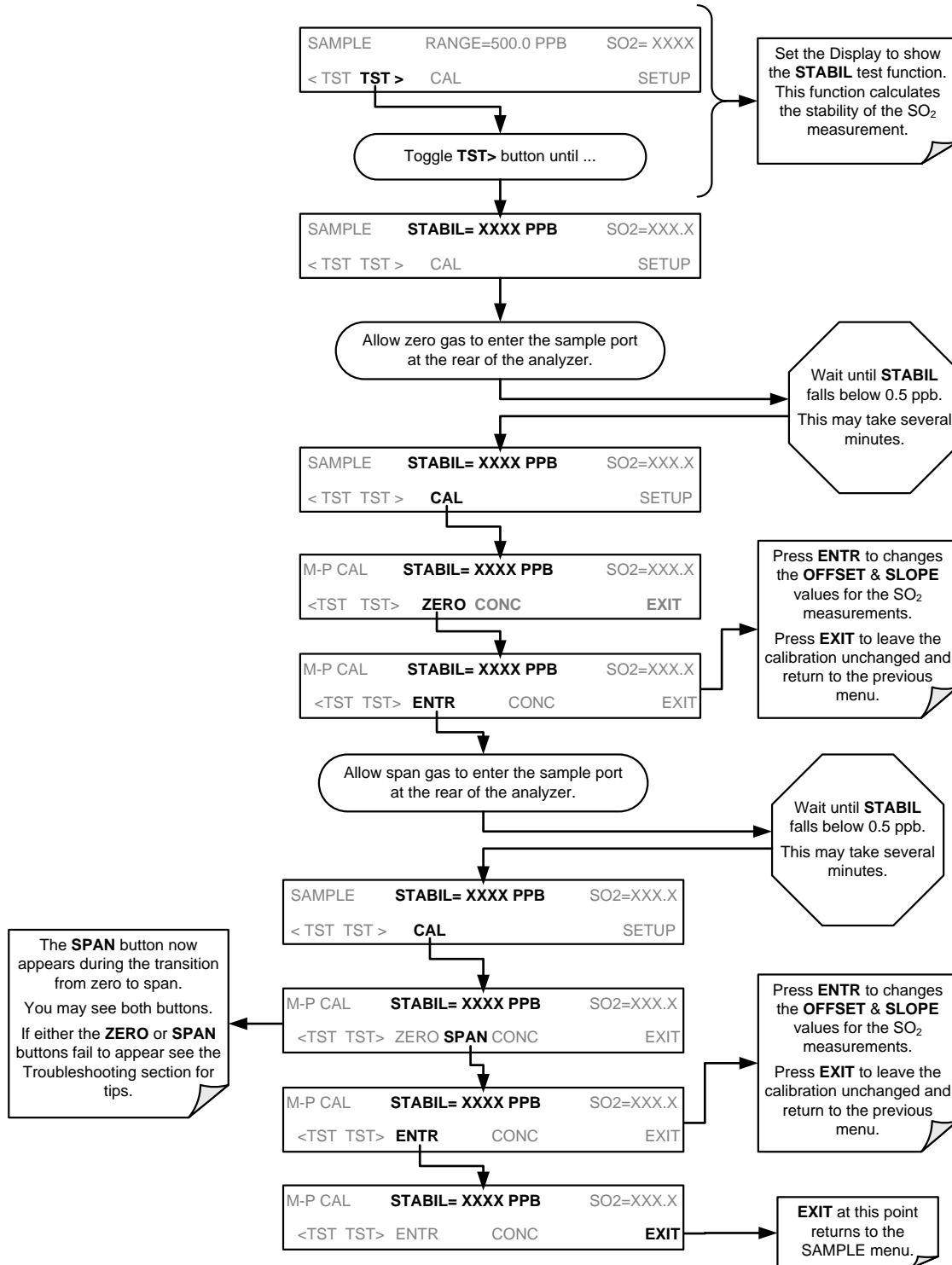


Figure 3-29: Zero/Span Calibration Procedure

**3.4.4.2. CALIBRATION PROCEDURE FOR THE O<sub>2</sub> OPTION**

If your analyzer is equipped with the optional O<sub>2</sub> sensor, this sensor should be calibrated during installation of the instrument. Refer to Section 9.10.1 for instructions.

**3.4.4.3. CALIBRATION PROCEDURE FOR THE CO<sub>2</sub> OPTION**

If your analyzer is equipped with the optional CO<sub>2</sub> sensor, this sensor should be calibrated during installation of the instrument. Refer to Section 9.10.2 for instructions.

**Note**

-----  
**Once you have completed the above set-up procedures, please fill out the Quality Questionnaire that was shipped with your unit and return it to Teledyne API. This information is vital to our efforts in continuously improving our service and our products. THANK YOU.**  
-----

## 4. OVERVIEW OF OPERATING MODES

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

### Note

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**Some control buttons on the touch screen do not appear if they are not applicable to the menu that you're in, the task that you are performing, the command you are attempting to send, or to incorrect settings input by the user. For example, the ENTR button may disappear if you input 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.**

---

The T100 software has a variety of operating modes. Most commonly, the analyzer will be operating in SAMPLE mode. In this mode, a continuous read-out of the SO<sub>2</sub> concentration can be viewed on the front panel and output as an analog voltage from rear panel terminals, calibrations can be performed, and TEST functions and WARNING messages can be examined.

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



Figure 4-1: Front Panel Display

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

In addition to **SAMPLE** and **SETUP**, other modes available are presented in Table 4-1.

Table 4-1: Analyzer Operating Modes

MODE	EXPLANATION
<b>DIAG</b>	One of the analyzer’s diagnostic modes is active (refer to Section 5.9).
<b>LO CAL A<sup>1</sup></b>	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer’s AUTOCAL feature
<b>LO CAL R<sup>1</sup></b>	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
<b>M-P CAL<sup>1</sup></b>	This is the basic calibration mode of the instrument and is activated by pressing the CAL button.
<b>SAMPLE</b>	Sampling normally, flashing text indicates adaptive filter is on.
<b>SAMPLE A</b>	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
<b>SETUP</b>	SETUP mode is being used to configure the analyzer. The gas measurement will continue during this process.
<b>SPAN CAL A<sup>2</sup></b>	Unit is performing SPAN calibration initiated automatically by the analyzer’s AUTOCAL feature
<b>SPAN CAL M<sup>2</sup></b>	Unit is performing SPAN calibration initiated manually by the user.
<b>SPAN CAL R<sup>2</sup></b>	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
<b>ZERO CAL A<sup>2</sup></b>	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature
<b>ZERO CAL M<sup>2</sup></b>	Unit is performing ZERO calibration procedure initiated manually by the user.
<b>ZERO CAL R<sup>2</sup></b>	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.
<sup>1</sup> Other calibration procedures under <b>CAL</b> mode are described separately in Section 9.	
<sup>2</sup> Only Appears on units with Z/S valve or IZS options.	

## 4.1. SAMPLE MODE

This is the analyzer's standard operating mode. In this mode, the instrument is analyzing SO<sub>2</sub> and calculating concentrations.

### 4.1.1. TEST FUNCTIONS

A series of test functions is available at the front panel while the analyzer is in **SAMPLE** mode. These parameters provide information about the present operating status of the instrument and are useful during troubleshooting (refer to Section 11.1.2). They can also be recorded in one of the DAS channels (refer to Section 7) for data analysis. To view the test functions, press one of the <**TST TST**> buttons repeatedly in either direction.

Table 4-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
RANGE	RANGE -- RANGE1 RANGE2	PPB, PPM, UGM & MGM	The Full Scale limit at which the reporting range of the analyzer's ANALOG OUTPUTS is currently set. THIS IS NOT the Physical Range of the instrument. Refer to Section 5.4 for more information. If DUAL or AUTO Range modes have been selected, two RANGE functions will appear, one for each range.
STABIL	STABILITY	mV	Standard deviation of SO <sub>2</sub> Concentration readings. Data points are recorded every ten seconds. The calculation uses the last 25 data points.
PRES	SAMPLE PRESSURE	in-Hg-A	The current pressure of the sample gas as it enters the sample chamber, measured between the SO <sub>2</sub> and Auto-Zero valves.
SAMP FL	SAMPLE FLOW	cm <sup>3</sup> /min (cc/m)	The flow rate of the sample gas through the sample chamber. This value is not measured but calculated from the sample pressure.
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 offset and 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 performed.
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.
SLOPE	SO <sub>2</sub> 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.
OFFSET	SO <sub>2</sub> 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	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 <sup>1</sup>	IZS TEMPERATURE <sup>1</sup>	°C	The current temperature of the internal zero/span option. Only appears when IZS option is enabled.
TEST <sup>2</sup>	TEST SIGNAL <sup>2</sup>	mV	Signal of a user-defined test function on output channel A4.
TIME	CLOCK TIME	hh:mm:ss	The current day time for DAS records and calibration events.
<sup>1</sup> Only appears if Internal Gas Span Generator option is installed.			
<sup>2</sup> Only appears if analog output A3 is actively reporting a test function.			

To view the TEST Functions press the following button sequence:

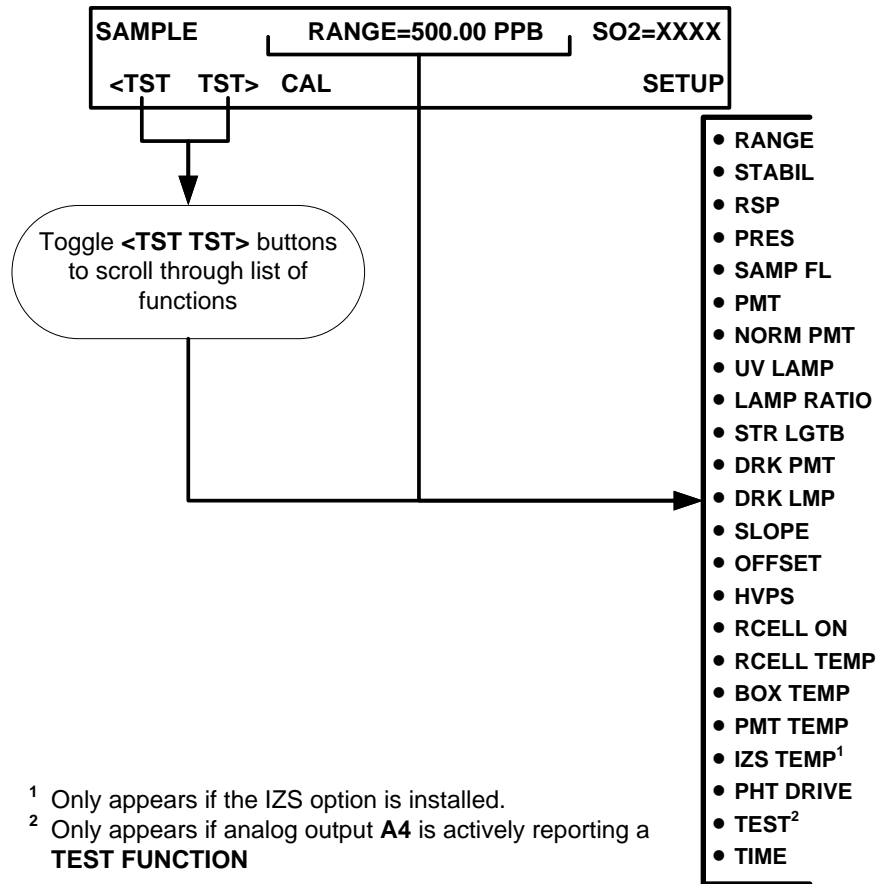


Figure 4-2: Viewing T100 TEST Functions

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

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

### 4.1.2. WARNING MESSAGES

The most common instrument failures will be reported as a warning on the analyzer's front panel and through the COMM ports. Section 11.1.1 explains how to use these messages to troubleshoot problems. Section 11.1.3 shows how to view and clear warning messages. Table 4-3 lists the warning messages for the current version of software.

Table 4-3: List of Warning Messages

MESSAGE	MEANING
<b>ANALOG CAL WARNING</b>	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
<b>BOX TEMP WARNING</b>	The temperature inside the T100 chassis is outside the specified limits.
<b>CANNOT DYN SPAN</b>	Remote span calibration failed while the dynamic span feature was set to turned on
<b>CANNOT DYN ZERO</b>	Remote zero calibration failed while the dynamic zero feature was set to turned on
<b>CONFIG INITIALIZED</b>	Configuration was reset to factory defaults or was erased.
<b>DARK CAL WARNING</b>	Dark offset above limit specified indicating that too much stray light is present in the sample chamber.
<b>DATA INITIALIZED</b>	DAS data storage was erased.
<b>HVPS WARNING</b>	High voltage power supply for the PMT is outside of specified limits.
<b>IZS TEMP WARNING</b>	On units with IZS options installed: The permeation tube temperature is outside of specified limits.
<b>PMT DET WARNING</b>	PMT detector output outside of operational limits.
<b>PMT TEMP WARNING</b>	PMT temperature is outside of specified limits.
<b>RCELL TEMP WARNING</b>	Sample chamber temperature is outside of specified limits.
<b>REAR BOARD NOT DET</b>	The CPU is unable to communicate with the motherboard.
<b>RELAY BOARD WARN</b>	The firmware is unable to communicate with the relay board.
<b>SAMPLE FLOW WARN</b>	The flow rate of the sample gas is outside the specified limits.
<b>SAMPLE PRESS WARN</b>	Sample pressure outside of operational parameters.
<b>SYSTEM RESET</b>	The computer was rebooted.
<b>UV LAMP WARNING</b>	The UV lamp intensity measured by the reference detector reading too low or too high

To view and clear warning messages, press:

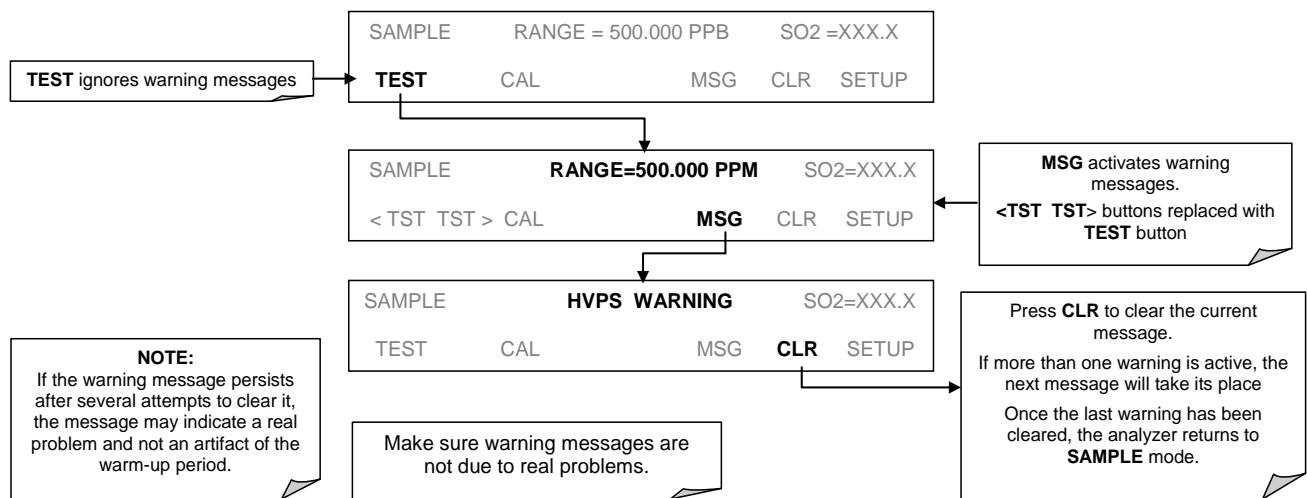


Figure 4-3: Viewing and Clearing T100 WARNING Messages



## 4.2. CALIBRATION MODE

Pressing the **CAL** button switches the analyzer into calibration mode. In this mode, the user can calibrate the instrument with the use of calibrated zero or span gases.

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

- The **CALZ** button is used to initiate a calibration of the zero point.
- The **CALS** button is used to calibrate the span point of the analyzer. It is recommended that this span calibration is performed at 80% of full scale of the analyzer's currently selected reporting range.

Because of their critical importance and complexity, calibration operations are described in detail in other sections of the manual:

- Section 9 details basic calibration and calibration check operations.
- Section 0 provides references for performing an EPA protocol calibration.

---

### IMPORTANT

#### IMPACT ON READINGS OR DATA

**To avoid inadvertent adjustments to critical settings, activate calibration security by enabling password protection in the SETUP – PASS menu (5.5).**

---

## 4.3. SETUP MODE

The **SETUP** mode is used to configure the analyzer's hardware and software features, perform diagnostic procedures, gather information on the instrument's performance and configure or access data from the internal data acquisition system (DAS). For a visual representation of the software menu trees, refer to Appendix A. Setup Mode is divided between Primary and Secondary Setup menus and can be protected through password security.

### 4.3.1. PASSWORD SECURITY

Setup Mode can be protected by password security through the SETUP>PASS menu (Section 5.5) to prevent unauthorized or inadvertent configuration adjustments.

### 4.3.2. PRIMARY SETUP MENU

**Table 4-4: Primary Setup Mode Features and Functions**

MODE OR FEATURE	CONTROL BUTTON	DESCRIPTION	MANUAL SECTION
Analyzer Configuration	<b>CFG</b>	Lists key hardware and software configuration information.	5.1
Auto Cal Feature	<b>ACAL</b>	Used to set up and operate the AutoCal feature. Only appears if the analyzer has one of the internal valve options installed.	5.2 & 9.8
Internal Data Acquisition (DAS)	<b>DAS</b>	Used to set up the DAS system and view recorded data.	5.3 & 7
Analog Output Reporting Range Configuration	<b>RNGE</b>	Used to configure the output signals generated by the instrument's Analog outputs.	5.4
Calibration Password Security	<b>PASS</b>	Turns the calibration password protection feature ON/OFF.	5.5
Internal Clock Configuration	<b>CLK</b>	Used to Set or adjust the instrument's internal clock.	5.6
Advanced <b>SETUP</b> features	<b>MORE</b>	This button accesses the instruments secondary setup menu.	See Table 4-5

### 4.3.3. SECONDARY SETUP MENU (SETUP>MORE)

**Table 4-5: Secondary Setup Mode Features and Functions**

MODE OR FEATURE	MENU ITEM	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	<b>COMM</b>	Used to set up and operate the analyzer's various external I/O channels including RS-232; RS 485, modem communication and/or Ethernet access.	5.7 & 6
System Status Variables	<b>VARs</b>	Used to view various variables related to the instrument's current operational status	5.8
System Diagnostic Features	<b>DIAG</b>	Used to access a variety of functions that are used to configure, test or diagnose problems with a variety of the analyzer's basic systems	5.9

#### IMPORTANT

#### IMPACT ON READINGS OR DATA

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

## 5. SETUP MENU

The SETUP menu is used to set instrument parameters for performing configuration, calibration, reporting and diagnostics operations according to user needs.

### 5.1. SETUP – CFG: CONFIGURATION INFORMATION

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

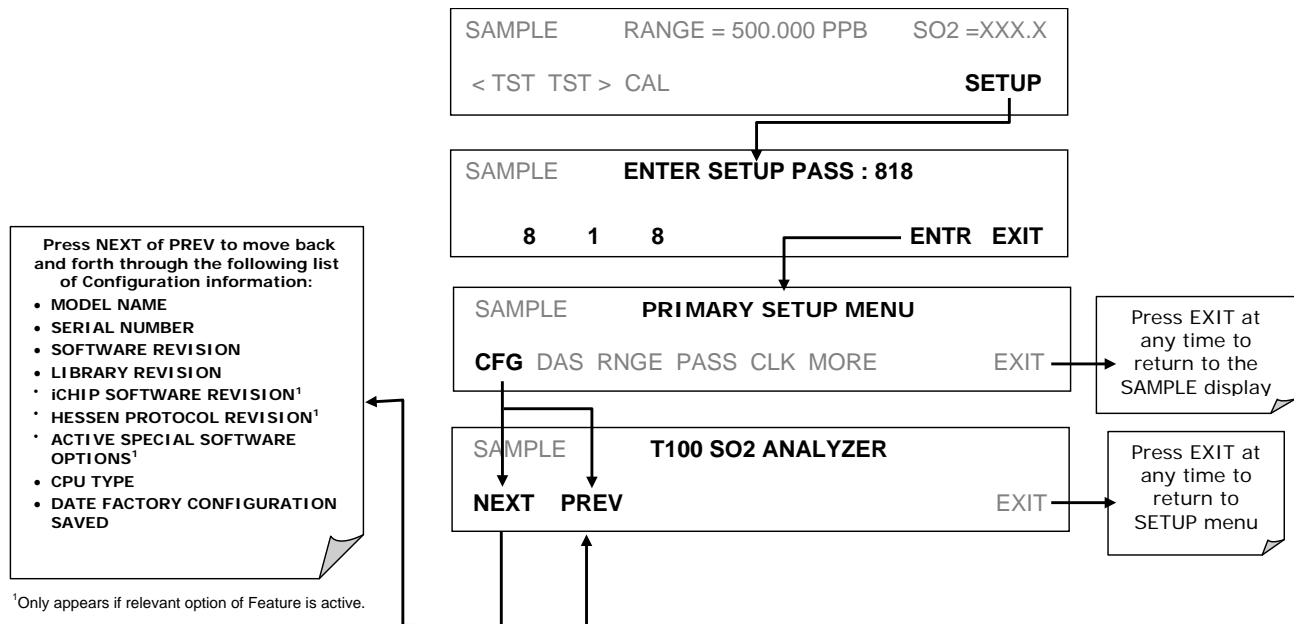


Figure 5-1: SETUP – Configuration Information

### 5.2. SETUP – ACAL: AUTOMATIC CALIBRATION OPTION

The menu button for this option appears only when the instrument has the zero span and/or IZS options. See Section 9.8 for details.

### 5.3. SETUP – DAS: INTERNAL DATA ACQUISITION SYSTEM

Use the SETUP>DAS menu to capture and record data. Refer to Section 7 for configuration and operation details.

### 5.4. SETUP – RNGE: ANALOG OUTPUT REPORTING RANGE CONFIGURATION

Use the SETUP>RNGE menu to configure output reporting ranges, including scaled reporting ranges to handle data resolution challenges. This section describes configuration for Single, Dual, and Auto Range modes.

#### 5.4.1. AVAILABLE ANALOG OUTPUT SIGNALS

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

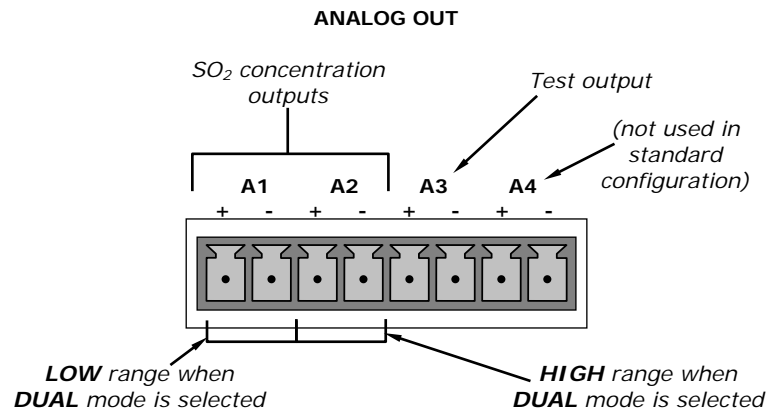


Figure 5-2: SETUP – Analog Output Connector

All three outputs can be configured either at the factory or by the user for full scale outputs of 0.1 VDC, 1VDC, 5VDC or 10VDC. Additionally A1 and A2 may be equipped with optional 0-20 mA DC current loop drivers and configured for any current output within that range (e.g. 0-20, 2-20, 4-20, etc.). The user may also adjust the signal level and scaling of the actual output voltage or current to match the input requirements of the recorder or data logger (Refer to Section 5.9.3.3 and 5.9.3.5).

In its basic configuration, the A1 and A2 channels of the T100 output a signal that is proportional to the SO<sub>2</sub> concentration of the sample gas. Several operating modes are available which allow:

- Single range mode (**SNGL** Mode, refer to Section 5.4.3.1): Both outputs are slaved together and will represent the same concentration span (e.g. 0-50 ppm); however their electronic signal levels may be configured for different ranges (e.g. 0-10 VDC vs. 0-.1 VDC – Refer to Section 5.9.3).
- Dual range mode (**DUAL** mode, refer to Section 5.4.3.2): The two outputs can be configured for separate and independent units of measure and measurement spans as well as separate electronic signal levels.

- Auto range mode (**AUTO** mode, refer to Section 5.4.3.3) gives the analyzer the ability to automatically switch the A1 and A2 analog outputs between two ranges (low and high) dynamically as the concentration value fluctuates.

**EXAMPLE:**

**A1 OUTPUT:** Output Signal = 0-5 VDC representing 0-1000 ppm concentration values

**A2 OUTPUT:** Output Signal = 0 – 10 VDC representing 0-500 ppm concentration values.

**A3 OUTPUT:** Test channel; e.g., PMT signal = 0-5V

Output **A4** is not available on the T100 Analyzer in standard configuration.

## 5.4.2. PHYSICAL RANGE VERSUS ANALOG OUTPUT REPORTING RANGES

The entire measurement range of the T100 is 0 – 20,000 ppb, but many applications use only a small part of the analyzer's full measurement range. This creates two performance challenges:

The width of the T100's physical range can create data resolution problems for most analog recording devices. For example, in an application where the expected concentration of SO<sub>2</sub> is typically less than 500 ppb, the full scale of expected values is only 0.25% of the instrument's full 20,000 ppb measurement range. Unmodified, the corresponding output signal would also be recorded across only 0.25% of the range of the recording device.

The T100 solves this problem by allowing the user to select a scaled reporting range for the analog outputs that only includes that portion of the physical range relevant to the specific application. Only the reporting range of the analog outputs is scaled, the physical range of the analyzer and the readings displayed on the front panel remain unaltered.

Applications where low concentrations of SO<sub>2</sub> are measured require greater sensitivity and resolution than typically necessary for measurements of higher concentrations.

The T100 solves this issue by using two hardware physical ranges that cover the instrument's entire 0 and 20,000 ppb measurement range: a 0 to 2,000 ppb physical range for increased sensitivity and resolution when measuring very low SO<sub>2</sub> concentrations, and a 0 to 20,000 ppb physical range for measuring higher SO<sub>2</sub> concentrations. The analyzer's software automatically selects which physical range is in effect based on the analog output reporting range selected by the user.

- If the high end of the selected reporting range is  $\leq 2,000$  ppb. The low physical range is selected.
- If the high end of the selected reporting range is  $\geq 2,001$  ppb. The high physical range is selected.

Once properly calibrated, the analyzer's front panel display will accurately report concentrations along the entire span of its 0 and 20,000 ppb physical range regardless of which reporting range has been selected for the analog outputs and which physical range is being used by the instrument's software.

### 5.4.3. REPORTING RANGE MODES: SINGLE, DUAL, AUTO RANGES

The T100 provides three analog output range modes to choose from:

- Single range (**SNGL**) mode sets a single maximum range for the analog output. If single range is selected (refer to Section 5.4.3.1) 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 for different ranges (e.g. 0-10 VDC vs. 0-.1 VDC – Refer to Section 5.9.3.1).
- Dual range (**DUAL**) allows the A1 and A2 outputs to be configured with different measurement spans (refer to Section 5.4.3.2).
- Auto range (**AUTO**) mode gives the analyzer the ability to output data via a low range and high range. When this mode is selected (refer to Section 5.4.3.3) the T100 will automatically switch between the two ranges dynamically as the concentration value fluctuates.

Also, in this mode the RANGE Test function displayed on the front panel during SAMPLE mode will be replaced by two separate functions, Range1 and Range2.

Range status is also output via the External Digital I/O Status Bits (refer to Section 8.1.1).

To select the Analog Output Range Type press:

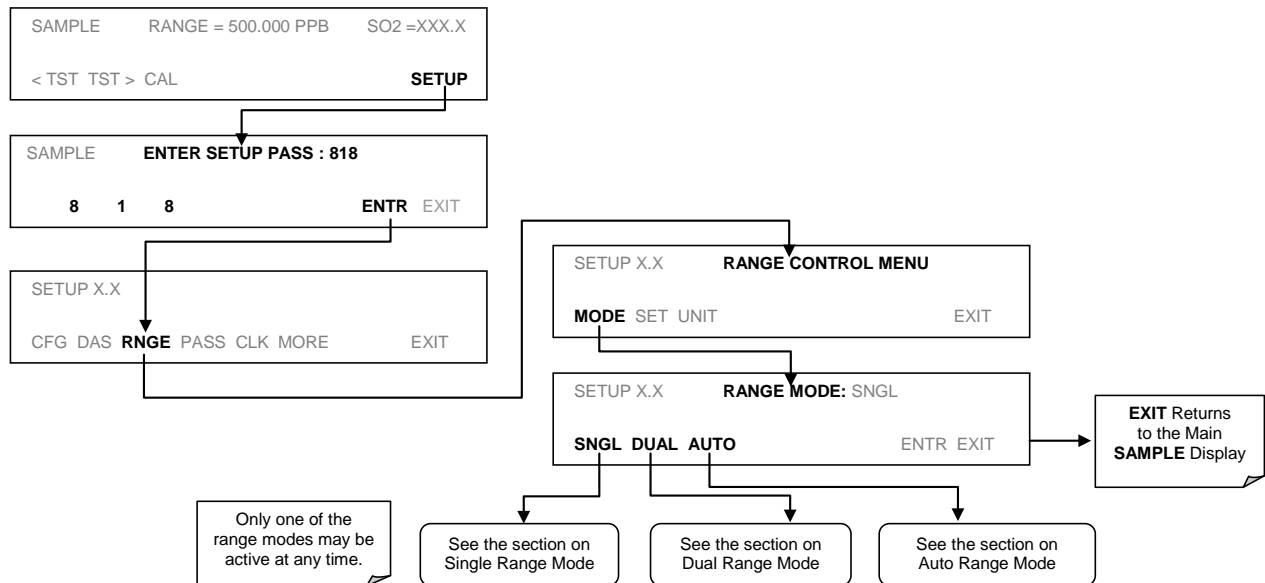


Figure 5-3: SETUP RNGE – Reporting Range Mode

5.4.3.1. SINGLE RANGE MODE (SNGL)

The default range mode for the analyzer is single range, in which all analog concentration outputs are set to the same reporting range. This reporting range can be set to any value between 0.1 ppb and 20,000 ppb.

While the two outputs always have the same reporting range, the span and scaling of their electronic signals may also be configured differently (e.g., **A1** = 0-10 V; **A2** = 0-0.1 V).

To select **SNGL** range mode and to set the upper limit of the range, press:

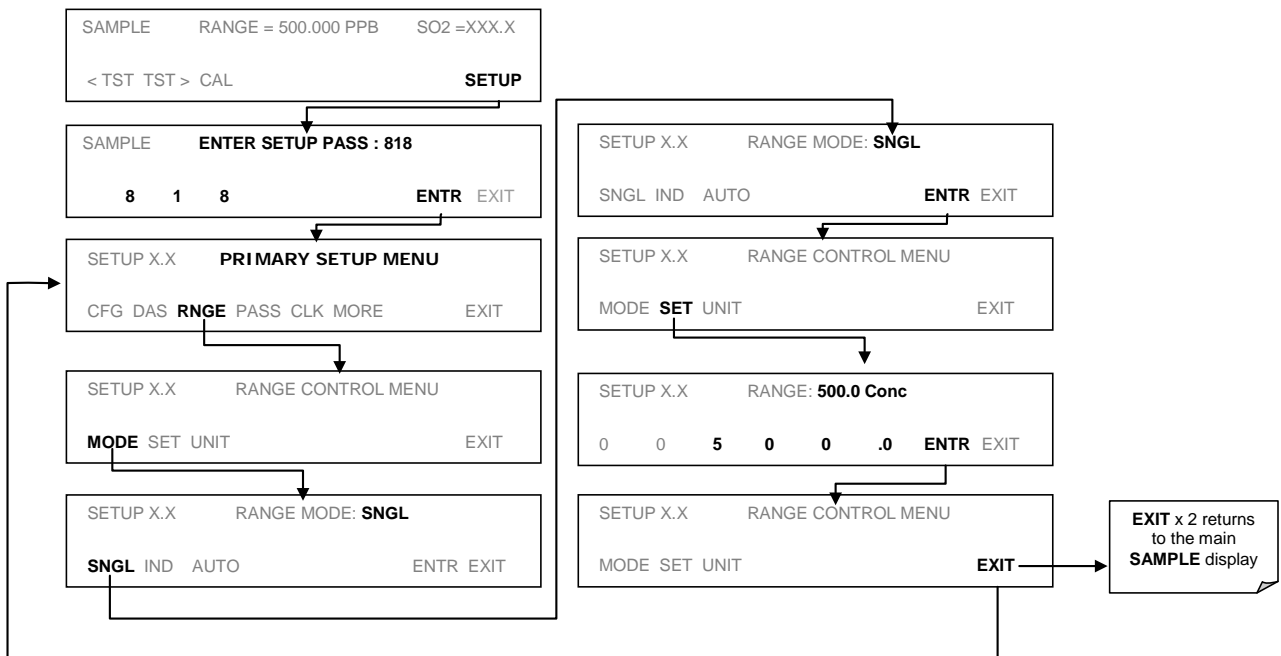


Figure 5-4: SETUP RNGE – Single Range Mode

### 5.4.3.2. DUAL RANGE MODE (DUAL)

Selecting Dual Range mode allows the **A1** and **A2** outputs to be configured with different reporting 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. For example: the low range can be set for a span of 0-150 ppb while the high range is set for 0-50 ppb.

In **DUAL** range mode the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

- RANGE1: The range setting for the A1 output.
- RANGE2: The range setting for the A2 output.

To set the ranges, press the following control button sequence:

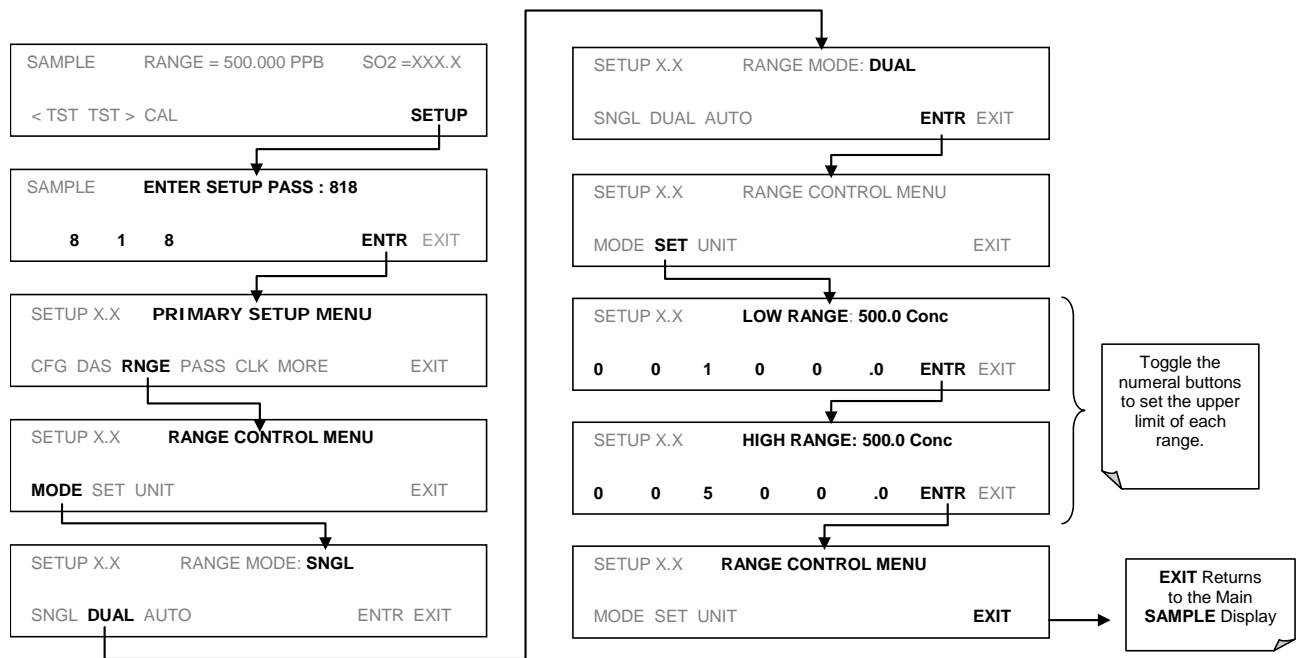


Figure 5-5: SETUP RNGE – Dual Range Mode

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

In **DUAL** range mode the **LOW** and **HIGH** ranges have separate slopes and offsets for computing SO<sub>2</sub> concentration. The two ranges must be independently calibrated.



5.4.3.3. 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 SO<sub>2</sub> concentration exceeds 98% of the low range span. The unit will return from high range back to low range once both the SO<sub>2</sub> 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 and automatically switches both outputs between ranges as described above. Also, the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

- **RANGE1**: The **LOW** range setting for all analog outputs.
- **RANGE2**: The **HIGH** range setting for all analog outputs.

The high/low range status is also reported through the external, digital status bits (refer to Section 8.1.1).

To set individual ranges press the following control button sequence.

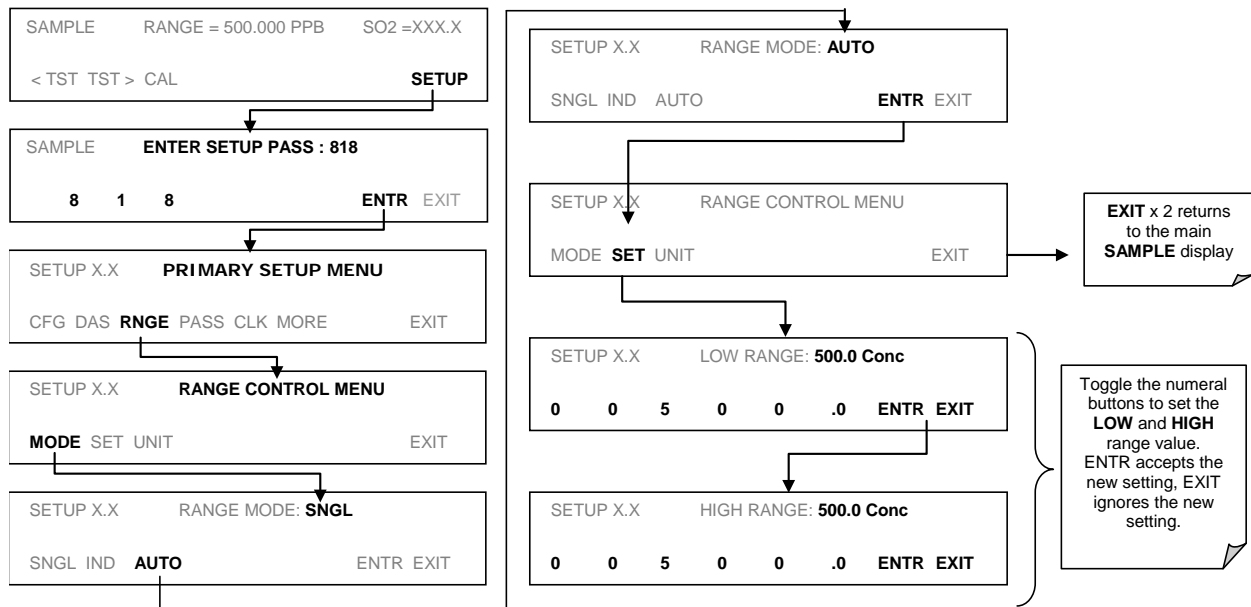


Figure 5-6: SETUP RNGE – Auto Range Mode

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

In **AUTO** range mode, the **LOW** and **HIGH** ranges have separate slopes and offsets for computing SO<sub>2</sub> concentration. The two ranges must be independently calibrated.

### 5.4.4. RANGE UNITS

The T100 can display concentrations in parts per billion (10<sup>9</sup> mols per mol, PPB), parts per million (10<sup>6</sup> mols per mol, PPM), micrograms per cubic meter (µg/m<sup>3</sup>, UGM) or milligrams per cubic meter (mg/m<sup>3</sup>, MGM). Changing units affects all of the display, analog outputs, COM port and DAS values for all reporting ranges regardless of the analyzer's range mode.

To change the concentration units:

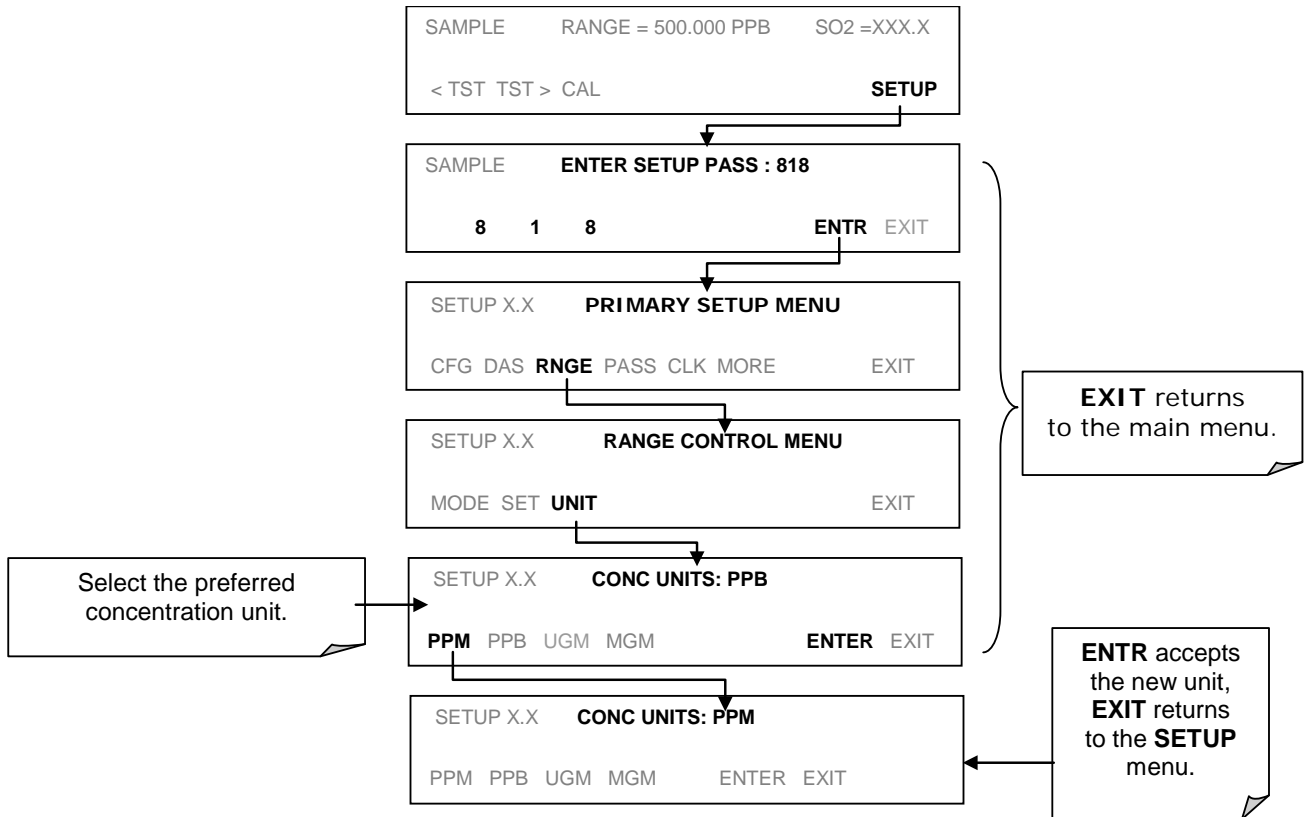


Figure 5-7: SETUP RNGE – Concentration Units Selection

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

Concentrations displayed in mg/m<sup>3</sup> and µg/m<sup>3</sup> use 0°C and 760 Torr as standard temperature and pressure (STP). Consult your local regulations for the STP used by your agency. See Section 5.4.4.1 for converting volumetric to mass units

#### 5.4.4.1. CONVERTING MICROGRAMS PER CUBIC METER TO PARTS PER MILLION

The conversion between micrograms per cubic meter and parts per million is based on standard conditions (0°C and 101.325 kPa) where one mole of an ideal gas occupies 22.414 L. Thus, converting the mass of the pollutant  $M_p$  in grams to its equivalent volume  $V_p$  in liters at standard temperature and pressure (STP) takes the following equation:

$$V_p = [(M_p)/(MW)] \times 22.414 \text{ L}\cdot\text{mol}^{-1}$$

Where MW is the molecular weight of the pollutant in units of grams per mole. For readings made at temperatures and pressures other than standard conditions, the standard volume, 22.414 L·mol<sup>-1</sup>, must be corrected. The ideal gas law to make the correction can be used:

$$(22.414 \text{ L}\cdot\text{mol}^{-1}) \times [(T_2)/(273 \text{ K})] \times [(101.325 \text{ kPa})/(P_2)]$$

Where  $T_2$  and  $P_2$  are the absolute temperature (in Kelvin) and absolute pressure (in kilopascals) at which the readings were made. Because parts per million is a volume ratio, it can be written as:

$$\text{ppm} = (V_p)/(V_a + V_p)$$

where  $V_a$  is the volume of the air in cubic meters at the temperature and pressure at which the measurement was taken. Then combine equations to yield:

$$\text{ppm} = \frac{\{[(M_p)/(MW)] \times (22.414 \text{ L}\cdot\text{mol}^{-1}) \times [(T_2)/(273 \text{ K})] \times [(101.325 \text{ kPa})/(P_2)]\}}{(V_a) \times (1000 \text{ L}\cdot\text{m}^{-3})}$$

where  $M_p$  is the mass of the pollutant of interest in micrograms. The factors converting micrograms to grams and liters to millions of liters cancel one another. Unless otherwise stated, it is assumed that  $V_a = 1.00 \text{ m}^3$

#### Example:

A 1-m<sup>3</sup> sample of air was found to contain 80 µg·m<sup>-3</sup> of SO<sub>2</sub>. The temperature and pressure were 25.0 °C and 103.193 kPa when the air sample was taken. What was the SO<sub>2</sub> concentration in parts per million?

#### Solution:

First, determine the MW of SO<sub>2</sub>:

$$\text{MW of SO}_2 = 32.06 + 2(15.9994) = 64.06 \text{ g}\cdot\text{mol}^{-1}$$

Next, convert the temperature from Celsius to Kelvin:

$$25^\circ\text{C} + 273 \text{ K} = 298 \text{ K}$$

Using the equation derived above, Concentration is:

$$\begin{aligned} & \{[(80 \text{ }\mu\text{g})/(64.06 \text{ g}\cdot\text{mol}^{-1})] \times (22.414 \text{ L}\cdot\text{mol}^{-1}) \times [(298 \text{ K})/(273 \text{ K})] \times [(101.325 \text{ kPa})/(103.193 \text{ kPa})]\} / [(1 \text{ m}^3) \times (1000 \text{ L}\cdot\text{m}^3)] \\ & = 0.030 \text{ ppm of SO}_2 \end{aligned}$$

### 5.4.5. DILUTION RATIO (OPTION)

The dilution ratio is a software option that allows the user to compensate for any dilution of the sample gas before it enters the sample inlet. Once the degree of dilution is known, add an appropriate scaling factor to the analyzer’s SO<sub>2</sub> concentration calculation so that the measurement range and concentration values reflect the undiluted values when shown on the instrument’s front panel display screen and reported via the analog and serial outputs.

Using the Dilution Ratio option is a 4-step process:

1. Select reporting range units: Follow the procedure in Section 5.4.4
2. Select the reporting range mode and set the reporting range upper limit (see Section 5.4).
  - Ensure that the upper span limit entered for the reporting range is the maximum expected concentration of the **undiluted** gas.
3. Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):

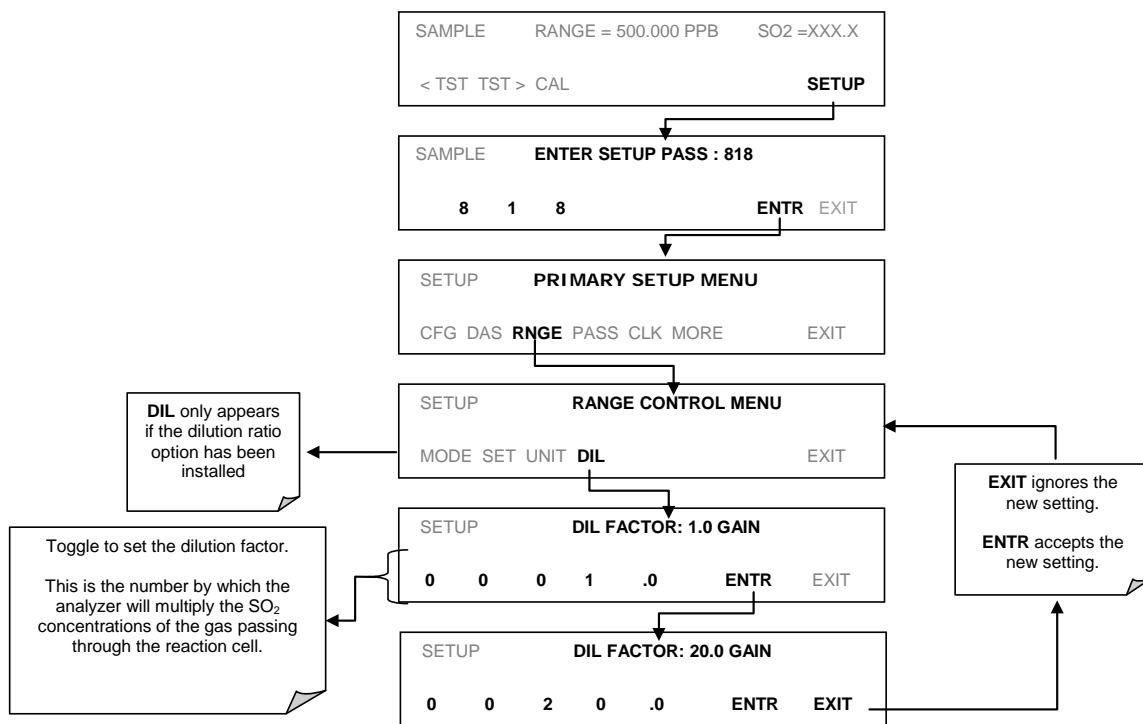


Figure 5-8: SETUP RNGE – Dilution Ratio

4. Calibrate the analyzer.
  - Ensure that the calibration span gas is either supplied through the same dilution system as the sample gas or has an appropriately lower actual concentration.

EXAMPLE: If the reporting range limit is set for 100 ppm and the dilution ratio of the sample gas is 20 gain, either:

- a span gas with the concentration of 100 ppm can be used if the span gas passes through the same dilution steps as the sample gas, or;
- a 5 ppm span gas must be used if the span gas **IS NOT** routed through the dilution system.

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

## IMPORTANT

### IMPACT ON READINGS OR DATA

Once the above settings have been entered, the instrument needs to be recalibrated using one of the methods discussed in Section 9.

## 5.5. SETUP – PASS: PASSWORD PROTECTION

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

Table 5-1: Password Levels

PASSWORD	LEVEL	MENU ACCESS ALLOWED
Null (000)	Operation	All functions of the main menu (top level (Primary) menu)
<b>101</b>	Configuration/Maintenance	Access to Primary and Secondary SETUP Menus when PASSWORD is enabled
<b>818</b>	Configuration/Maintenance	Access to Secondary SETUP Submenus <b>VARS</b> and <b>DIAG</b> whether PASSWORD is enabled or disabled.

To enable or disable passwords, press:

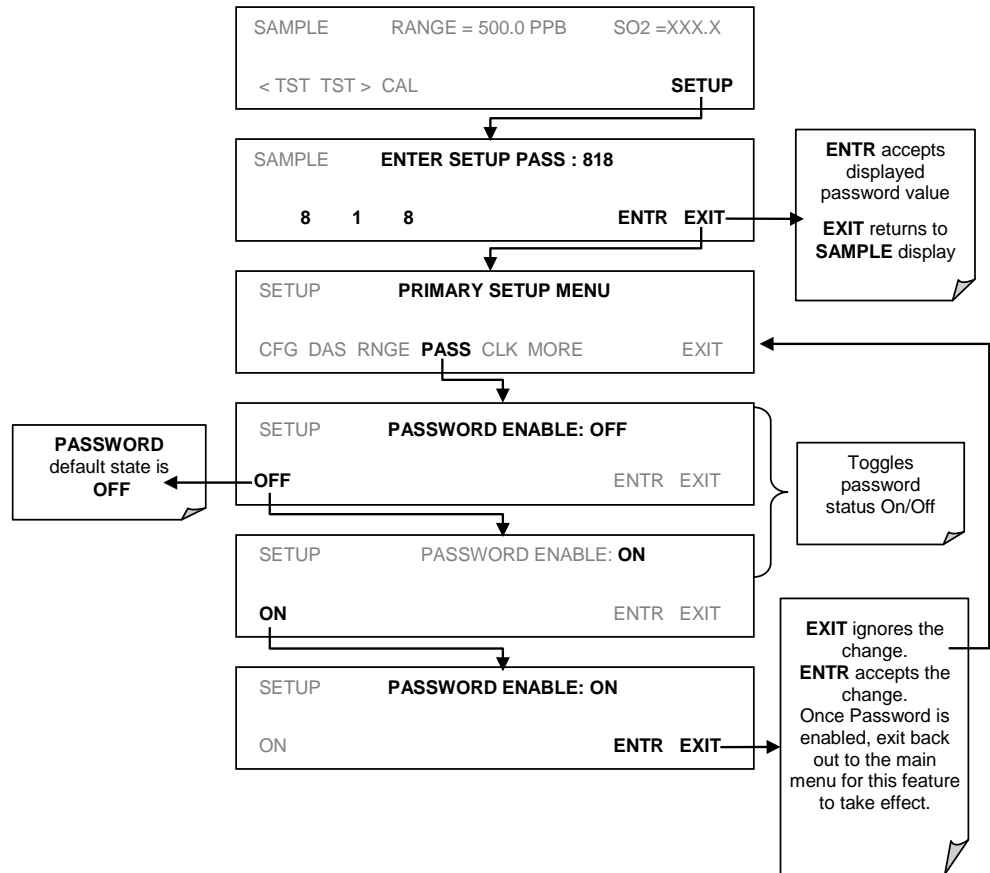


Figure 5-9: SETUP – Enable Password Security

If the password feature is enabled, the default password displayed will be 000 upon entering either Calibration or Setup Mode, and the new password must be input. Example follows for Calibration Mode:

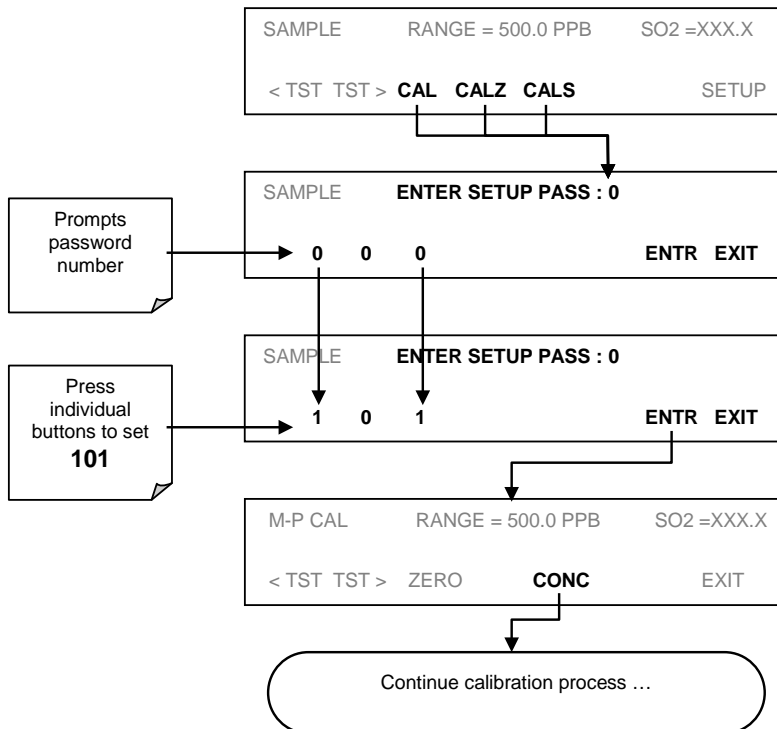


Figure 5-10: SETUP – Enter Calibration Mode Using Password

## 5.6. SETUP – CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK

The T100 has a built-in clock for the AutoCal timer, Time TEST functions, and time stamps on COM port messages and DAS data entries. To set the time-of-day, press:

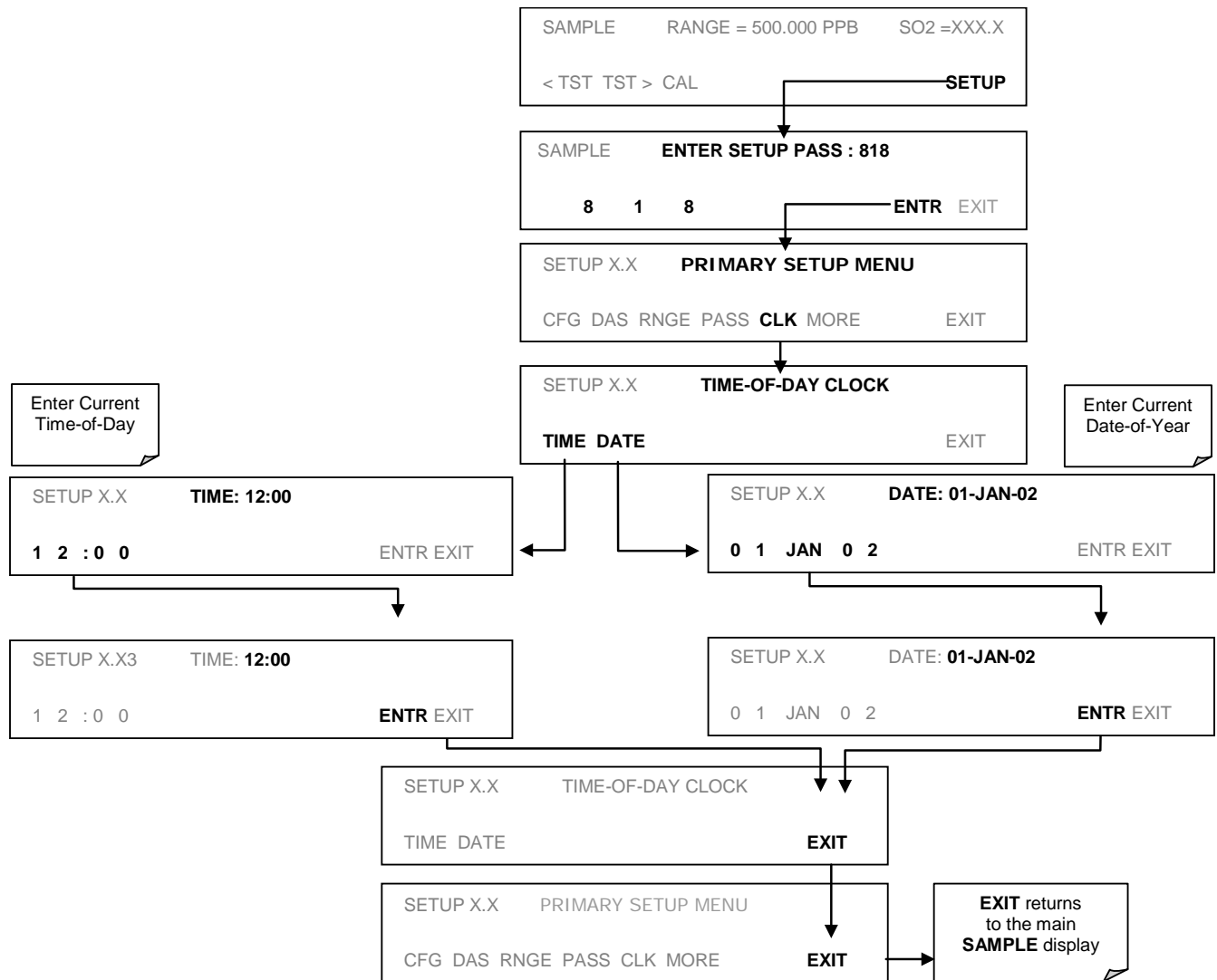


Figure 5-11: SETUP – Clock

In order to compensate for CPU clocks, which may run fast or slow, there is a variable (in the **SETUP>MORE>VARS** menu) to speed up or slow down the clock by a fixed amount every day. To change this variable, press:



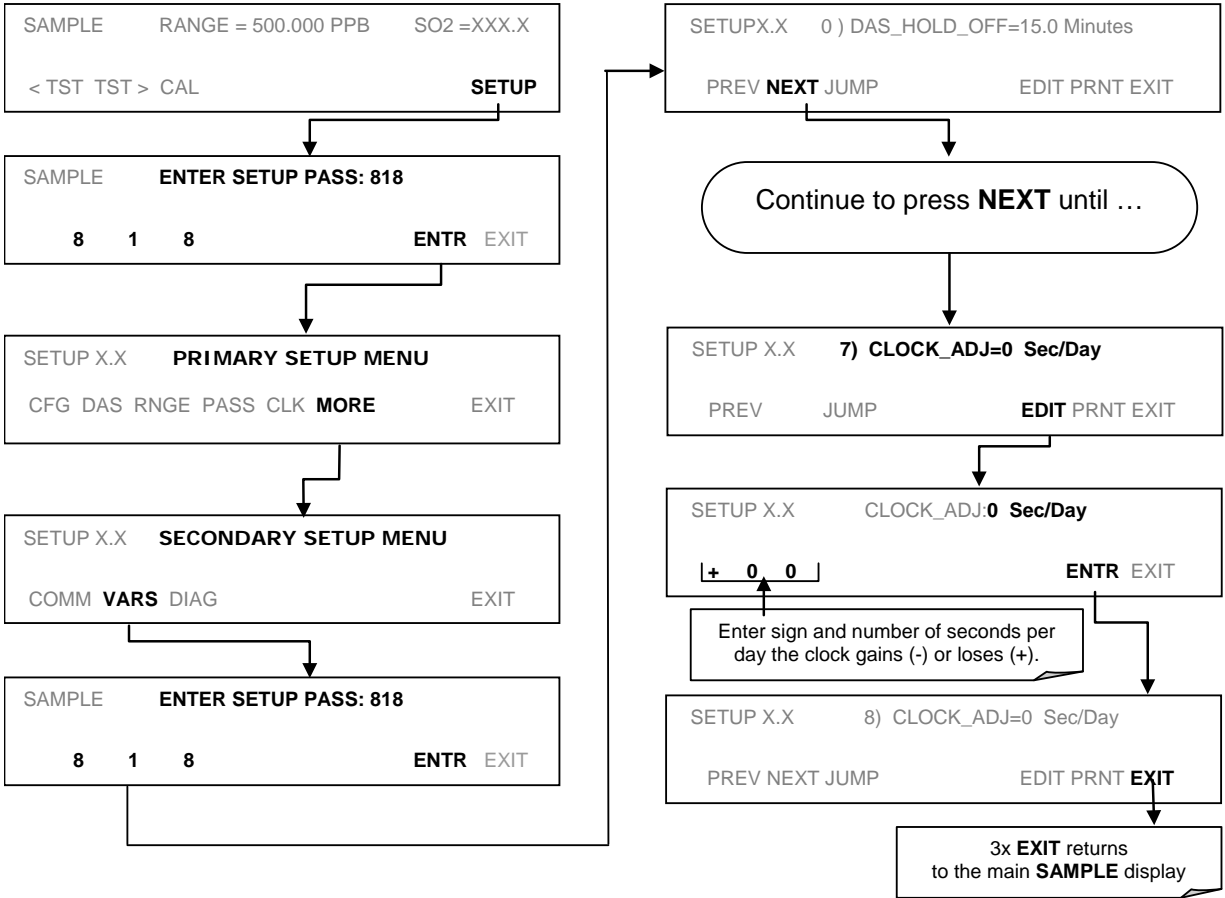


Figure 5-12: SETUP – Clock Speed Variable

## 5.7. SETUP – COMM: COMMUNICATIONS PORTS

This section introduces the communications setup menu; Section 6 provides the setup instructions and operation information. Press **SETUP>ENTR>MORE>COMM** to arrive at the communications menu.

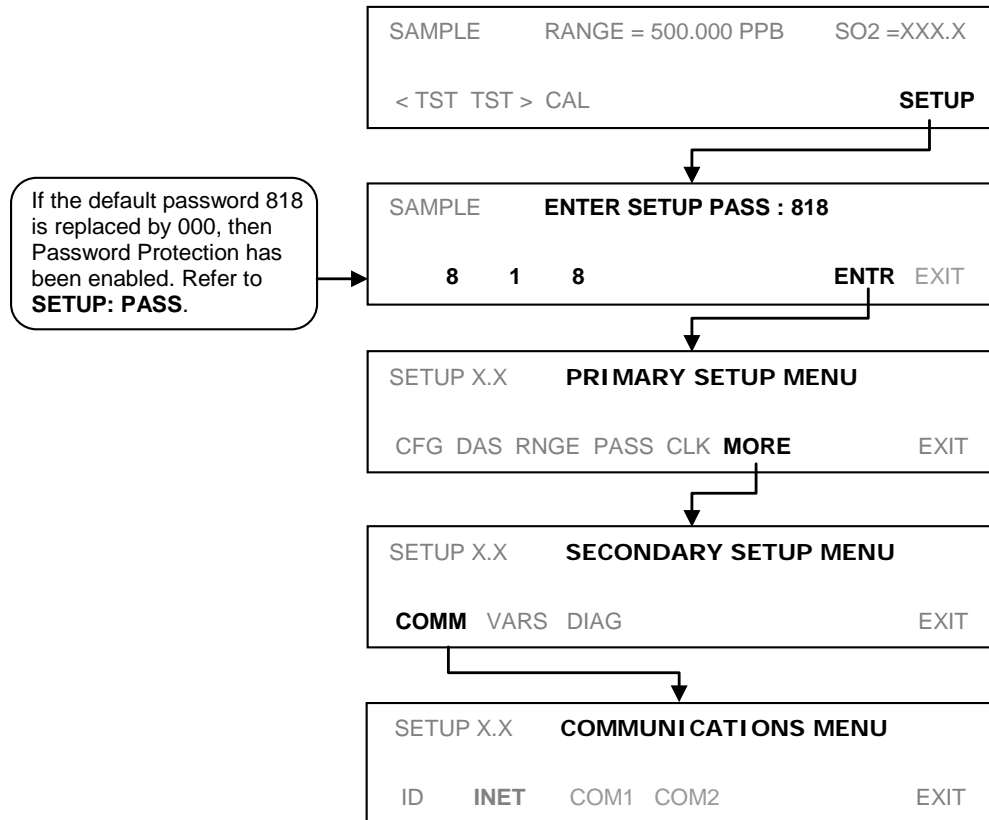
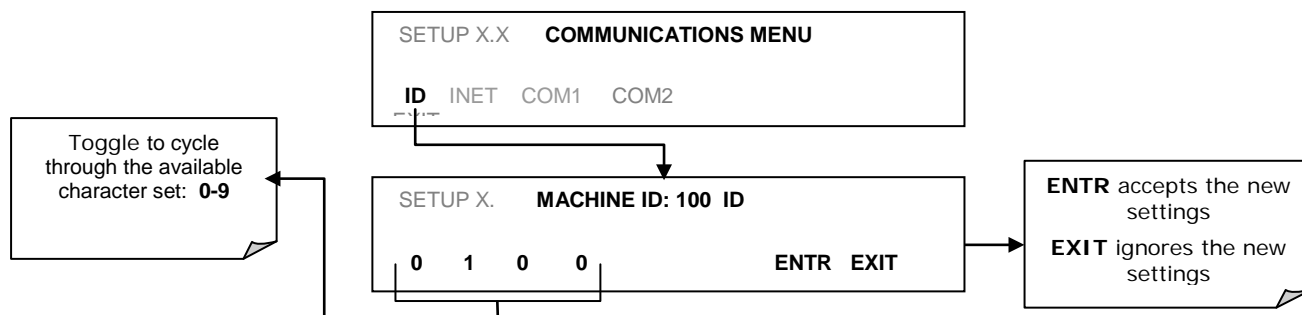


Figure 5-13: SETUP – COMM Menu

### 5.7.1. ID (INSTRUMENT IDENTIFICATION)

In the **SETUP>MORE>COMM** menu press **ID** to display and/or change the Machine ID, which must be changed to a unique identifier (number) when more than one instrument of the same model is used in a multidrop configuration (Section 3.3.1.8) or when applying MODBUS protocol (Section 6.6.1). The default ID is typically the same as the model number; for the Model T100, the ID is 0100 (but could be 0000). Press any button(s) in the MACHINE ID menu (Figure 5-14) until the Machine ID Parameter field displays the desired identifier.



**Figure 5-14: COMM – Machine ID**

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

### 5.7.2. INET (ETHERNET)

Use SETUP>COMM>INET to configure Ethernet communications, whether manually or via DHCP. Please see Section 6.5 for configuration details.

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

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

- configure communication modes (Section 6.2.1)
- view/set the baud rate (Section 6.2.2)
- test the connections of the com ports (Section 6.2.3).

Configuring COM1 or COM2 requires setting the DCE DTE switch on the rear panel. Section 6.1 provides DCE DTE information.

## 5.8. SETUP – VARS: VARIABLES SETUP AND DEFINITION

Through the SETUP>MORE>VARS menu there are several-user adjustable software variables that define certain operational parameters. Usually, these variables are automatically set by the instrument’s firmware, but can be manually re-defined using the VARS menu. Table 5-2 lists the variables that are available within the 818 password protected level.

**Table 5-2: Variable Names (VARS) Revision 1.0.3**

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES
0	DAS_HOLD_OFF	Changes the internal data acquisition system (DAS) hold-off time, which is the duration when data are not stored in the DAS because the software considers the data to be questionable. That is the case during warm-up or just after the instrument returns from one of its calibration modes to SAMPLE mode. DAS_HOLD_OFF can be disabled entirely in each DAS channel.	Can be between 0.5 and 20 minutes Default=15 min.
1	TPC_ENABLE	Enables or disables the temperature and pressure compensation (TPC) feature (refer to Section 12.7.3).	ON/OFF
2	RCELL_SET	Sets the sample chamber temperature. Increasing or decreasing this temperature will increase or decrease the rate at which SO <sub>2</sub> * decays into SO <sub>2</sub> (refer to Section 12.1.1). Do not adjust this setting unless under the direction of Teledyne API Technical Support personnel.	30° C - 70° C Default= 50° C
3	IZS_SET	Sets the IZS option temperature. Increasing or decreasing this temperature will increase or decrease the permeation rate of the IZS source (refer to Sections 3.3.2.4, 9.5, 9.6).	30° C - 70° C Default= 50° C
4	DYN_ZERO	Dynamic zero automatically adjusts offset and slope of the SO <sub>2</sub> response when performing a zero point calibration during an AutoCal (refer to Section 9).	ON/OFF
5	DYN_SPAN	Dynamic span automatically adjusts slope and slope of the SO <sub>2</sub> response when performing a zero point calibration during an AutoCal (refer to Section 9). Note that the DYN_ZERO and DYN_SPAN features are not allowed for applications requiring EPA equivalency.	ON/OFF
6	CONC_PRECISION	Allows the user to set the number of significant digits to the right of the decimal point display of concentration and stability values.	AUTO, 1, 2, 3, 4 Default=AUTO
7	CLOCK_ADJ	Adjusts the speed of the analyzer’s clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast. (See Section 5.6).	-60 to +60 s/day
8	SERVICE_CLEAR	ON resets the service interval timer. Returns to OFF upon reset.	ON/OFF
9	TIME_SINCE_SVC	Number of hours since last service.	0-500000
10	SVC_INTERVAL	Sets the interval between service reminders.	0-100000

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

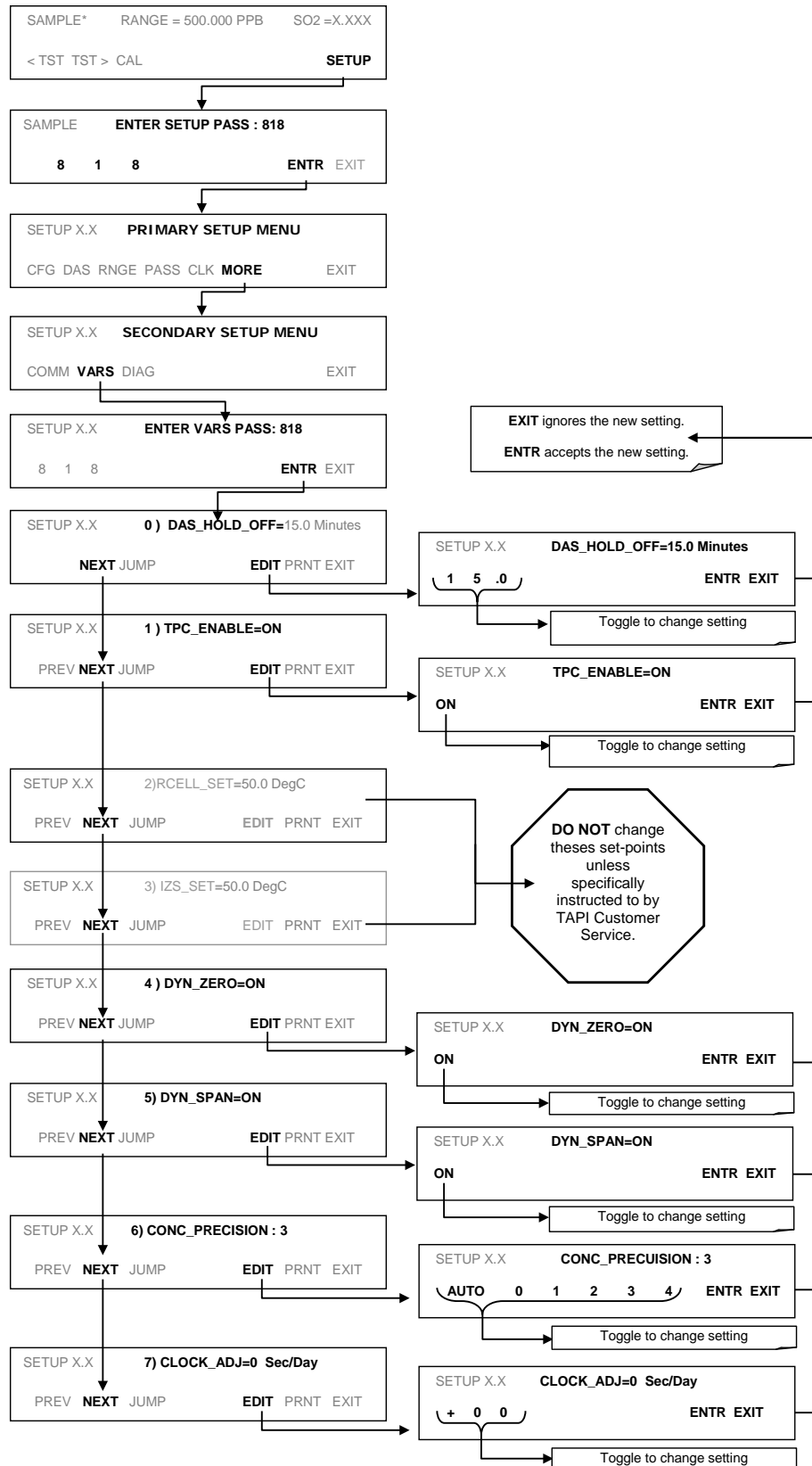


Figure 5-15: SETUP – VARS Menu

## 5.9. SETUP – DIAG: DIAGNOSTICS FUNCTIONS

The SETUP>MORE>DIAG menu provides a series of diagnostic functions whose parameters are dependent on firmware revision (refer to the menu trees in Appendix A). Table 5-3 describes the functions and provides a cross-reference to the details for each in the remainder of this section. These functions can be used as tools in a variety of troubleshooting and diagnostic procedures.

**Table 5-3: T100 Diagnostic (DIAG) Functions**

DIAGNOSTIC FUNCTION AND MEANING	FRONT PANEL MODE INDICATOR	SECTION
<b>SIGNAL I/O:</b> Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled ON and OFF.	DIAG I/O	5.9.1
<b>ANALOG OUTPUT:</b> When entered, the analyzer performs an analog output step test. This can be used to calibrate a chart recorder or to test the analog output accuracy.	DIAG AOUT	5.9.2
<b>ANALOG I/O CONFIGURATION:</b> Analog input/output parameters are available for viewing and configuration.	DIAG AIO	5.9.3
<b>OPTIC TEST:</b> When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT (Fig. 10-15). This diagnostic tests the response of the PMT without having to supply span gas.	DIAG OPTIC	5.9.4
<b>ELECTRICAL TEST:</b> When activated, the analyzer performs an electric test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	DIAG ELEC	5.9.5
<b>LAMP CALIBRATION:</b> The analyzer records the current voltage output of the UV source reference detector. This value is used by the CPU to calculate the lamp ration used in determining the SO <sub>2</sub> concentration	DIAG LAMP	5.9.6
<b>PRESSURE CALIBRATION:</b> The analyzer records the current output of the sample gas pressure sensor. This value is used by the CPU to compensate the SO <sub>2</sub> concentration when the TPC feature (Section 12.7.3) is enabled (Table 5-2).	DIAG PCAL	5.9.7
<b>FLOW CALIBRATION:</b> This function is used to calibrate the gas flow output signals of sample gas and ozone supply. These settings are retained when exiting DIAG.	DIAG FCAL	5.9.8
<b>TEST CHAN OUTPUT:</b> Configures the A4 analog output channel.	DIAG TCHN	5.9.9

To access the **DIAG** functions press the following buttons:

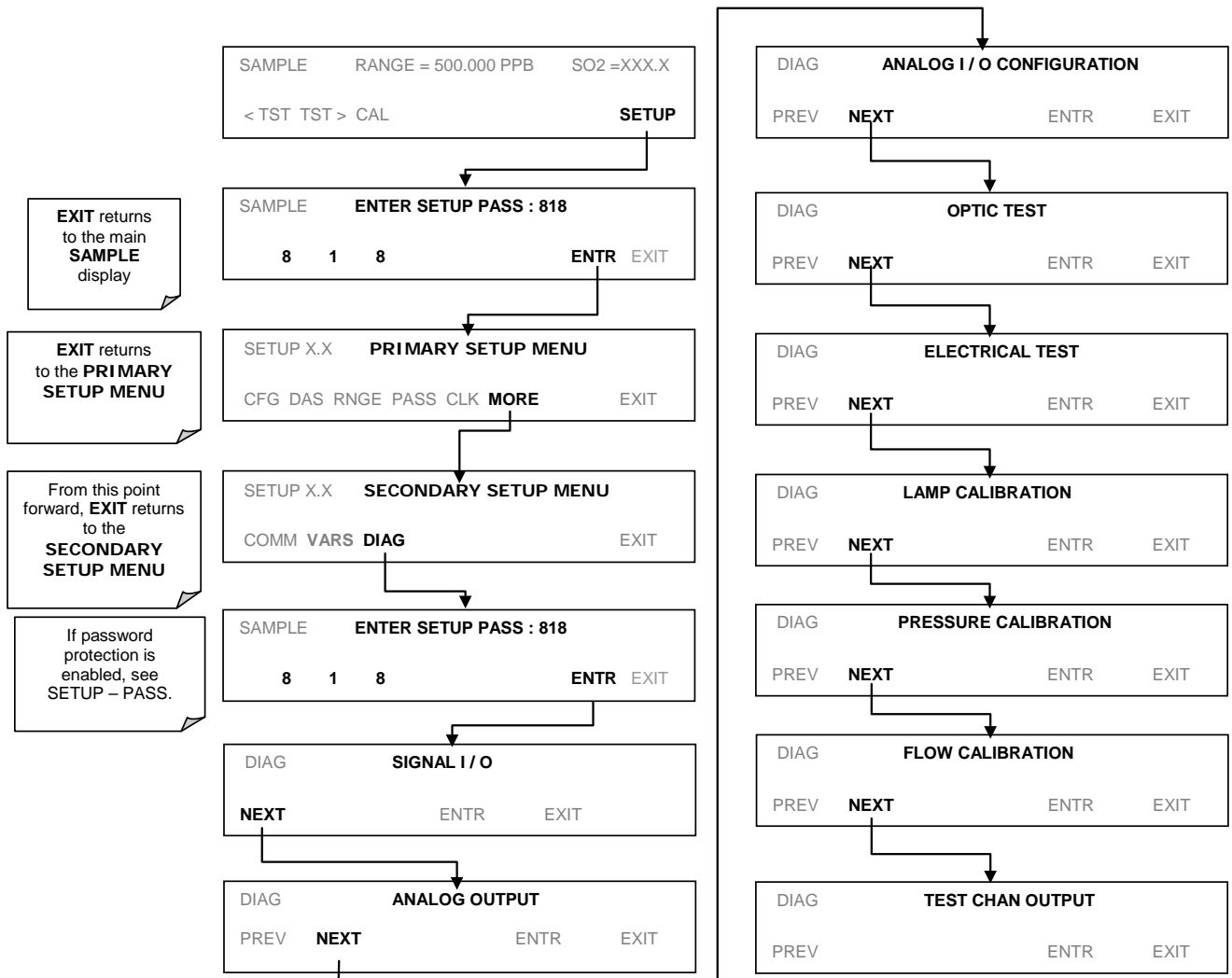


Figure 5-16: DIAG Menu

### 5.9.1. SIGNAL I/O

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

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

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

Access the signal I/O test mode from the DIAG Menu (refer to Figure 5-16), then press:

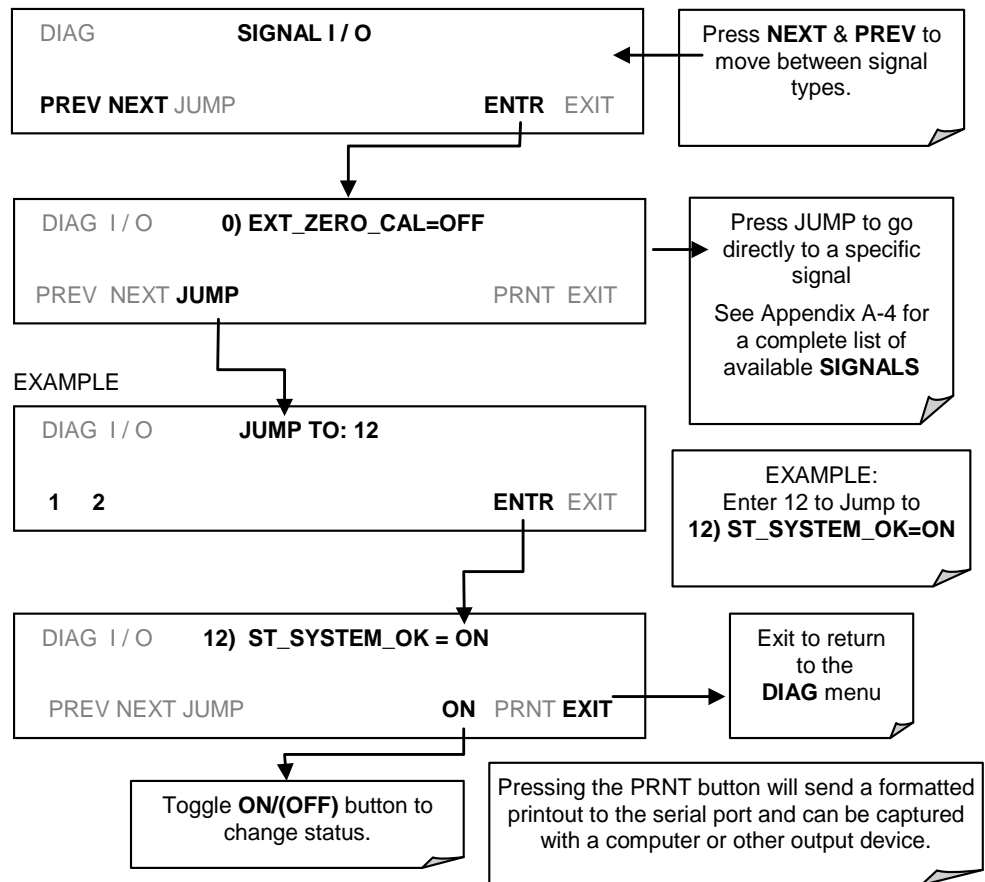


Figure 5-17: DIAG – Signal I/O Menu



### 5.9.2. ANALOG OUTPUT STEP TEST

Analog Output (DIAG AOUT) is used as a step test to check the accuracy and proper operation of the analog outputs. The test forces all four analog output channels to produce signals ranging from 0% to 100% of the full scale range in 20% increments. This test is useful to verify the operation of the data logging/recording devices attached to the analyzer.

Access the Analog Output Step Test from the DIAG Menu (refer to Figure 5-16), then press:

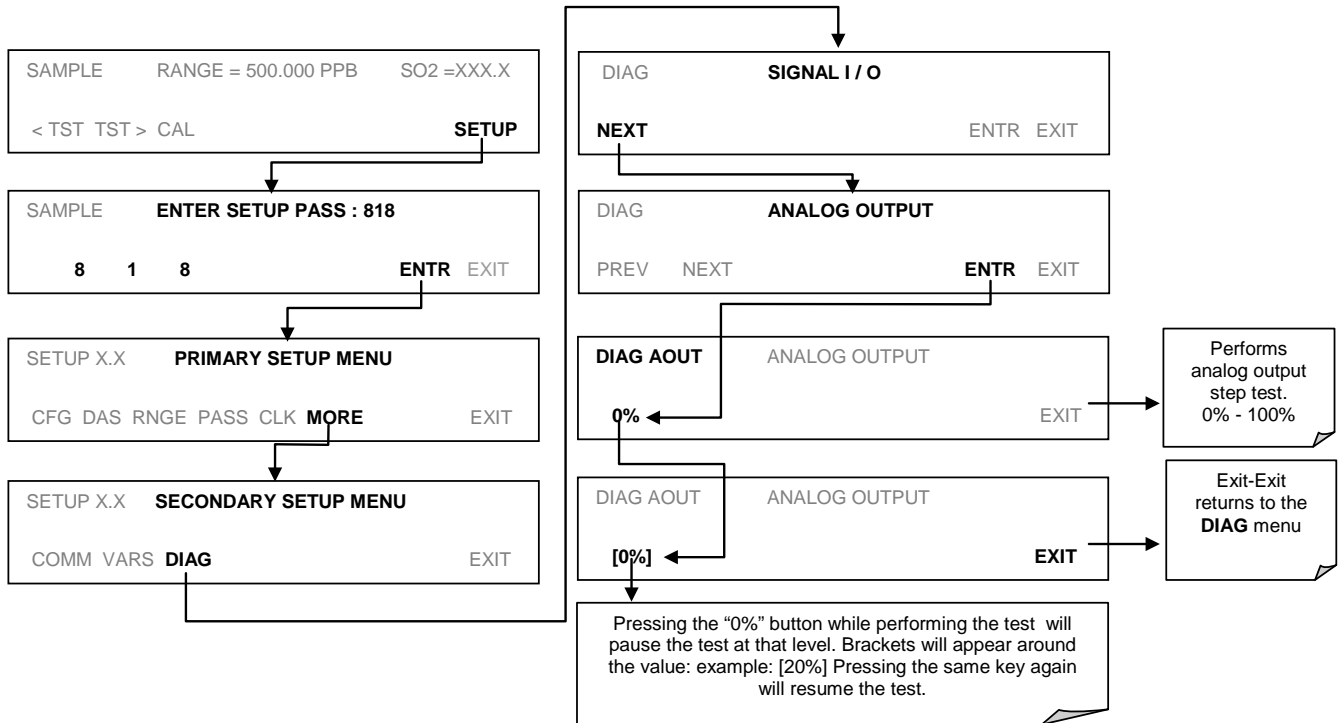


Figure 5-18: DIAG – Analog Output Menu

### 5.9.3. ANALOG I/O CONFIGURATION

Table 6-8 lists the analog I/O functions that are available in the T100.

**Table 5-4: DIAG - Analog I/O Functions**

SUB MENU	FUNCTION
<b>AOUTS CALIBRATED:</b>	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
<b>CONC_OUT_1</b>	Sets the basic electronic configuration of the A1 analog output (SO <sub>2</sub> ). There are three options: <ul style="list-style-type: none"> <li>• <b>RANGE:</b> Selects the signal type (voltage or current loop) and full scale level of the output.</li> <li>• <b>REC_OFS:</b> Allows setting a voltage offset (not available when RANGE is set to Current Loop (<b>CURR</b>)).</li> <li>• <b>AUTO_CAL:</b> Performs the same calibration as AOUT CALIBRATED, but on this one channel only.</li> </ul> NOTE: Any change to RANGE or REC_OFS requires recalibration of this output.
<b>CONC_OUT_2</b>	Same as for CONC_OUT_1 but for analog channel 2 (SO <sub>2</sub> )
<b>TEST OUTPUT</b>	Same as for CONC_OUT_1 but for analog channel 3 (TEST)
<b>CONC_OUT_3</b>	(Not available in the analyzer's standard configuration; applies when optional sensor installed).
<b>AIN CALIBRATED</b>	Shows the calibration status (YES/NO) and initiates a calibration of the analog input channels.
<b>XIN1</b> . . . <b>XIN8</b>	For each of 8 external analog inputs channels, shows the gain, offset, engineering units, and whether the channel is to show up as a Test function.

**Table 5-5: Analog Output Voltage Ranges**

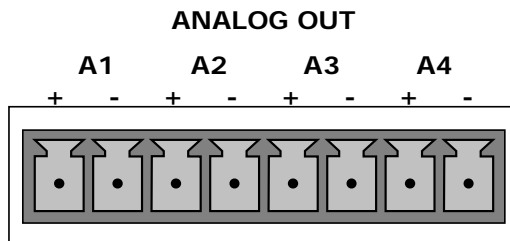
RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-0.1 V	-5 mV	+105 mV
0-1 V	-0.05 V	+1.05 V
0-5 V	-0.25 V	+5.25 V
0-10 V	-0.5 V	+10.5 V
The default offset for all ranges is 0 VDC.		

The following DC current output limits apply to the current loop modules:

**Table 5-6: Analog Output Current Loop Range**

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-20 mA	0 mA	20 mA

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



Refer to Figure 3-4 for the location of the analog output connector on the instrument's rear panel and Table 3-6 for pin assignments.

5.9.3.1. ANALOG OUTPUT SIGNAL TYPE AND RANGE SPAN SELECTION

To select an output signal type (DC Voltage or current) and level for one output channel, activate the **ANALOG I/O CONFIGURATION MENU** from the **DIAG** Menu (S), then press:

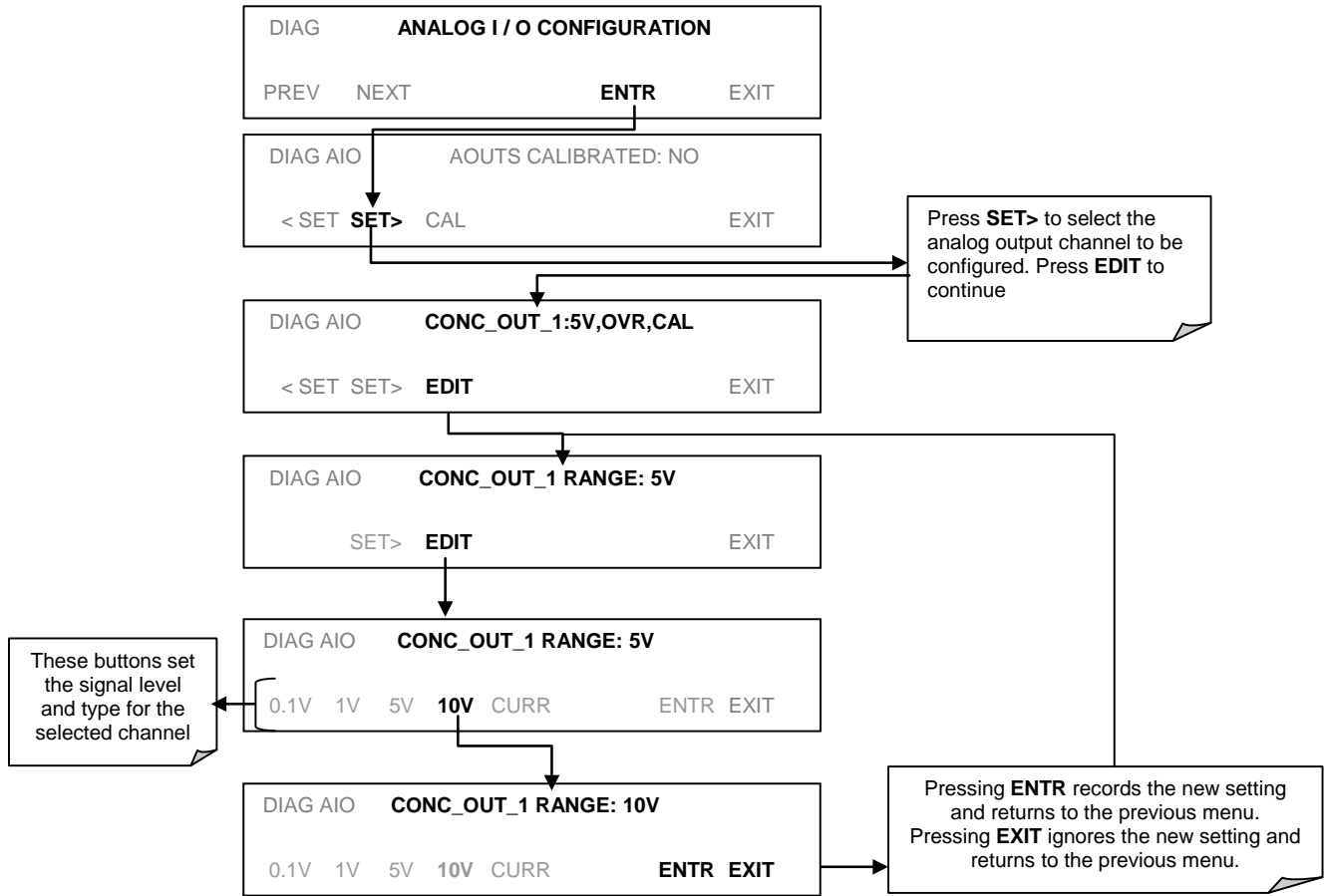


Figure 5-19: DIAG – Analog I/O Configuration Menu

### 5.9.3.2. ANALOG OUTPUT CALIBRATION MODE

Analog output calibration should to be carried out on first startup of the analyzer (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically, either as a group or individually, or adjusted manually.

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

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

To calibrate the outputs as a group, activate the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:

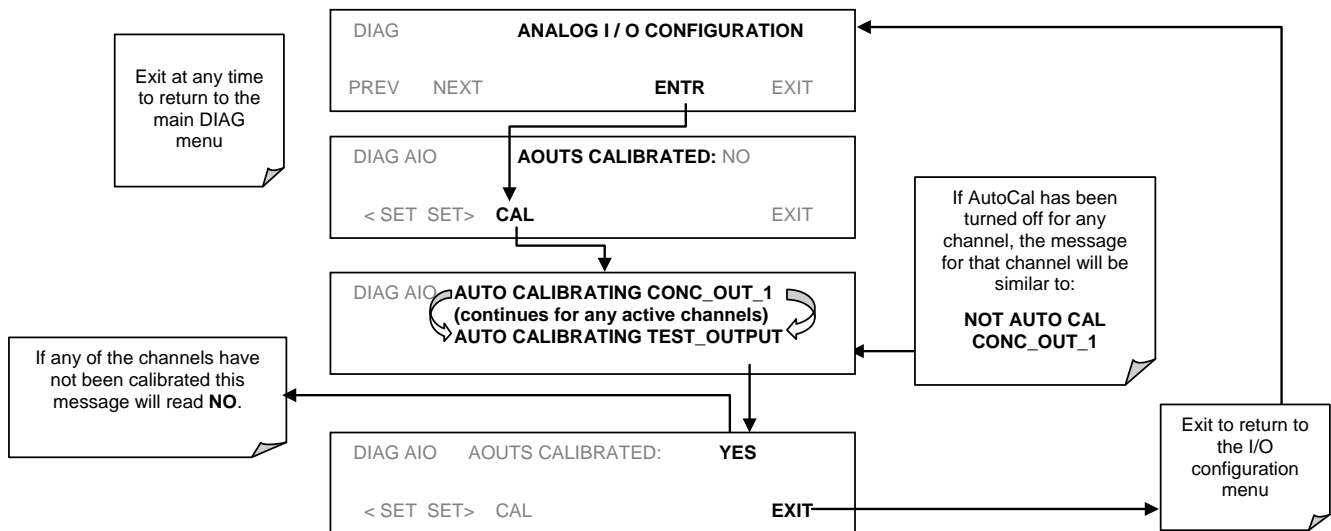


Figure 5-20: DIAG – Analog Output Calibration Mode

To automatically calibrate a single analog channel from the DIAG Menu (refer to Figure 5-16), press:

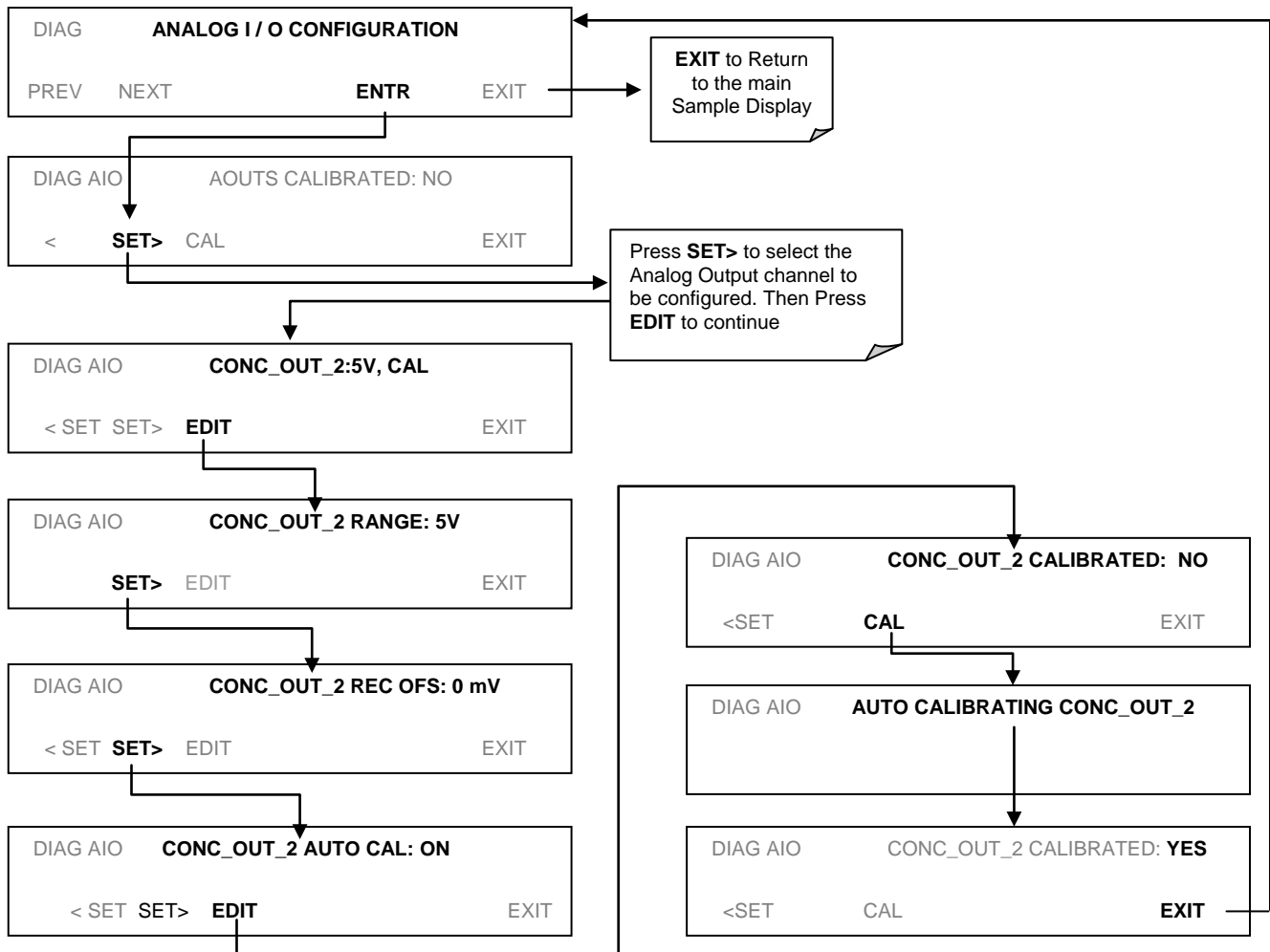


Figure 5-21: DIAG – Analog Output Calibration Mode – Single Analog Channel

To select manual output calibration for a particular channel, access the Analog I/O Configuration from the DIAG Menu (refer to Figure 5-16), then press:

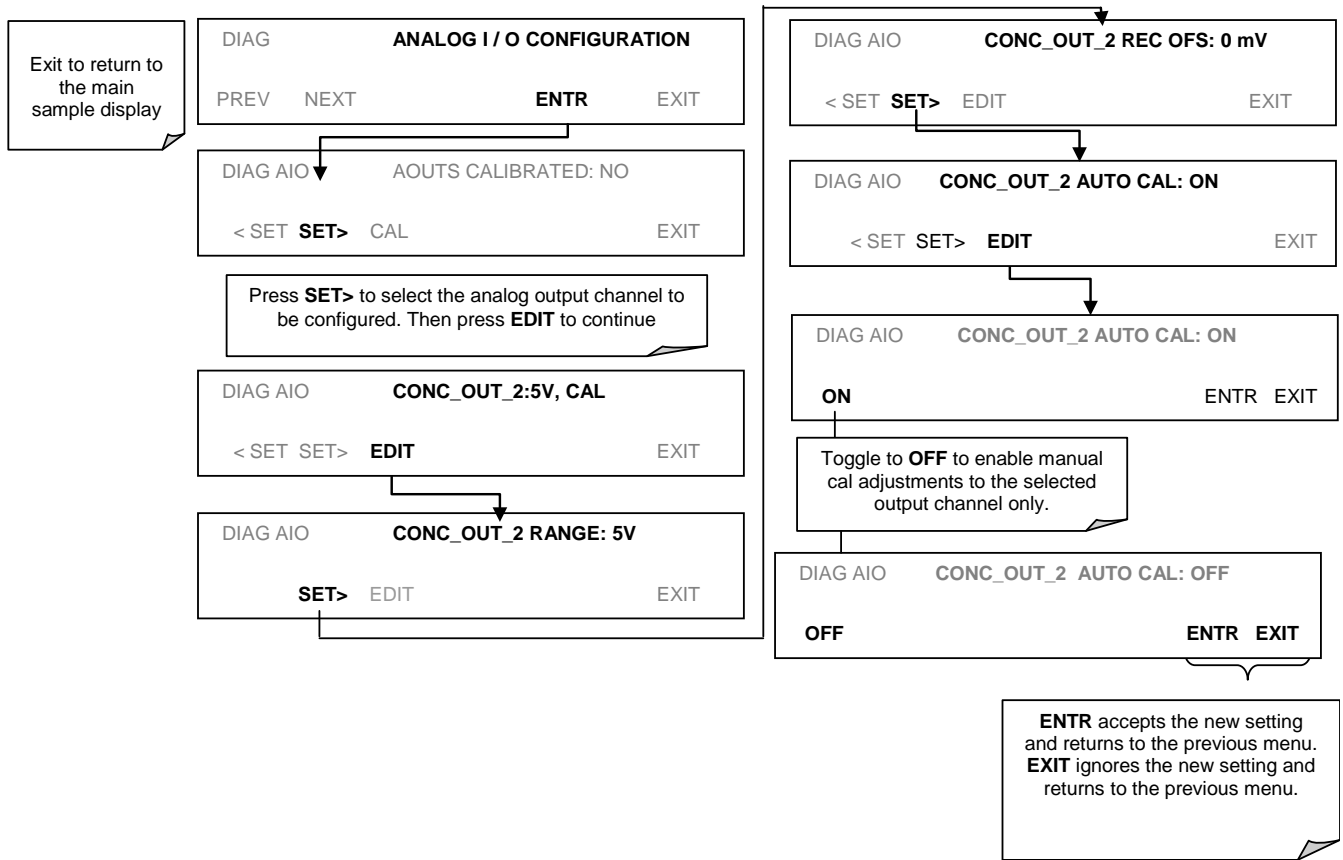


Figure 5-22: DIAG – Analog Output – Auto Cal or Manual Cal Selection for Channels

Now the analog output channels should either be automatically calibrated or they should be set to manual calibration, which is described next.

5.9.3.3. MANUAL ANALOG OUTPUT CALIBRATION AND VOLTAGE ADJUSTMENT

For highest accuracy, the voltages of the analog outputs can be manually calibrated. Calibration is done through the instrument software with a voltmeter connected across the output terminals (refer to Figure 5-23). Adjustments are made using the control buttons by setting the zero-point first and then the span-point (refer to Table 5-7).

The software allows this adjustment to be made in 100, 10 or 1 count increments.

Table 5-7: Voltage Tolerances for Analog Output Calibration

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE
0.1 VDC	±0.0005V	90 mV	±0.001V
1 VDC	±0.001V	900 mV	±0.001V
5 VDC	±0.002V	4500 mV	±0.003V
10 VDC	±0.004V	4500 mV	±0.006V

IMPORTANT

IMPACT ON READINGS OR DATA

Outputs configured for 0.1V full scale should always be calibrated manually.

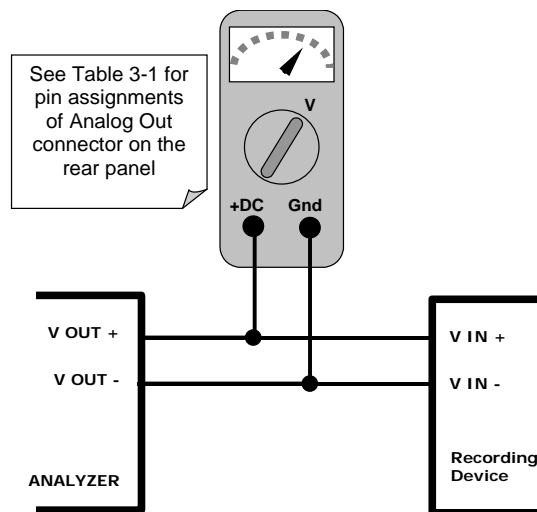


Figure 5-23: Setup for Calibrating Analog Outputs



To make these manual adjustments, turn off the **AOUT** auto-calibration feature (refer to Section 5.9.3.2). Activate the **ANALOG I/O CONFIGURATION MENU** from the **SETUP>MORE>DIAG** Menu (refer to Figure 5-16), then press:

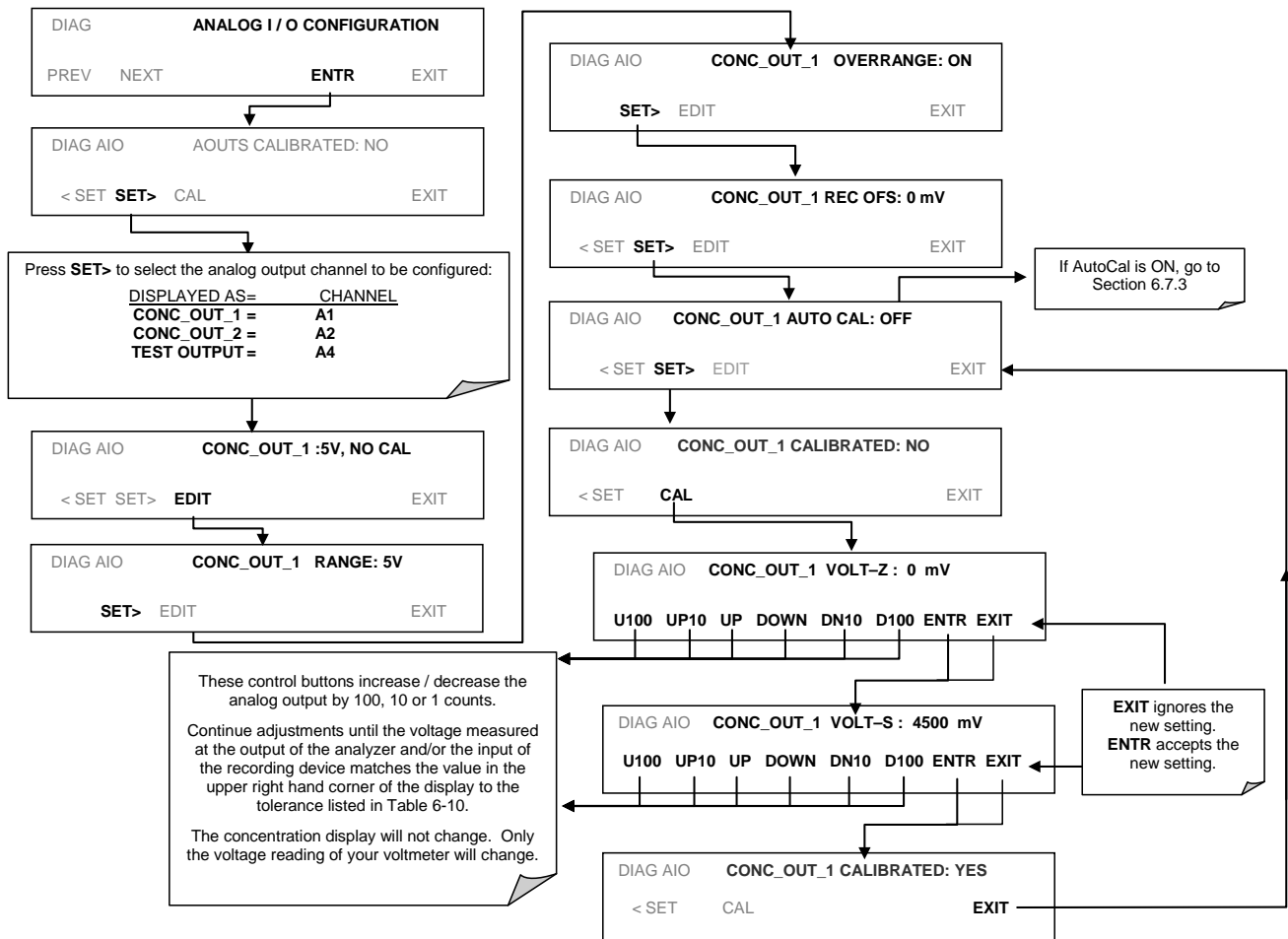


Figure 5-24: Analog Output – Voltage Adjustment

5.9.3.4. ANALOG OUTPUT OFFSET ADJUSTMENT

Some analog signal recorders require that the zero signal to be 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 T100 by defining a zero offset, a small voltage (e.g., 10% of span), which can be added to the signal of individual output channels by activating the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:

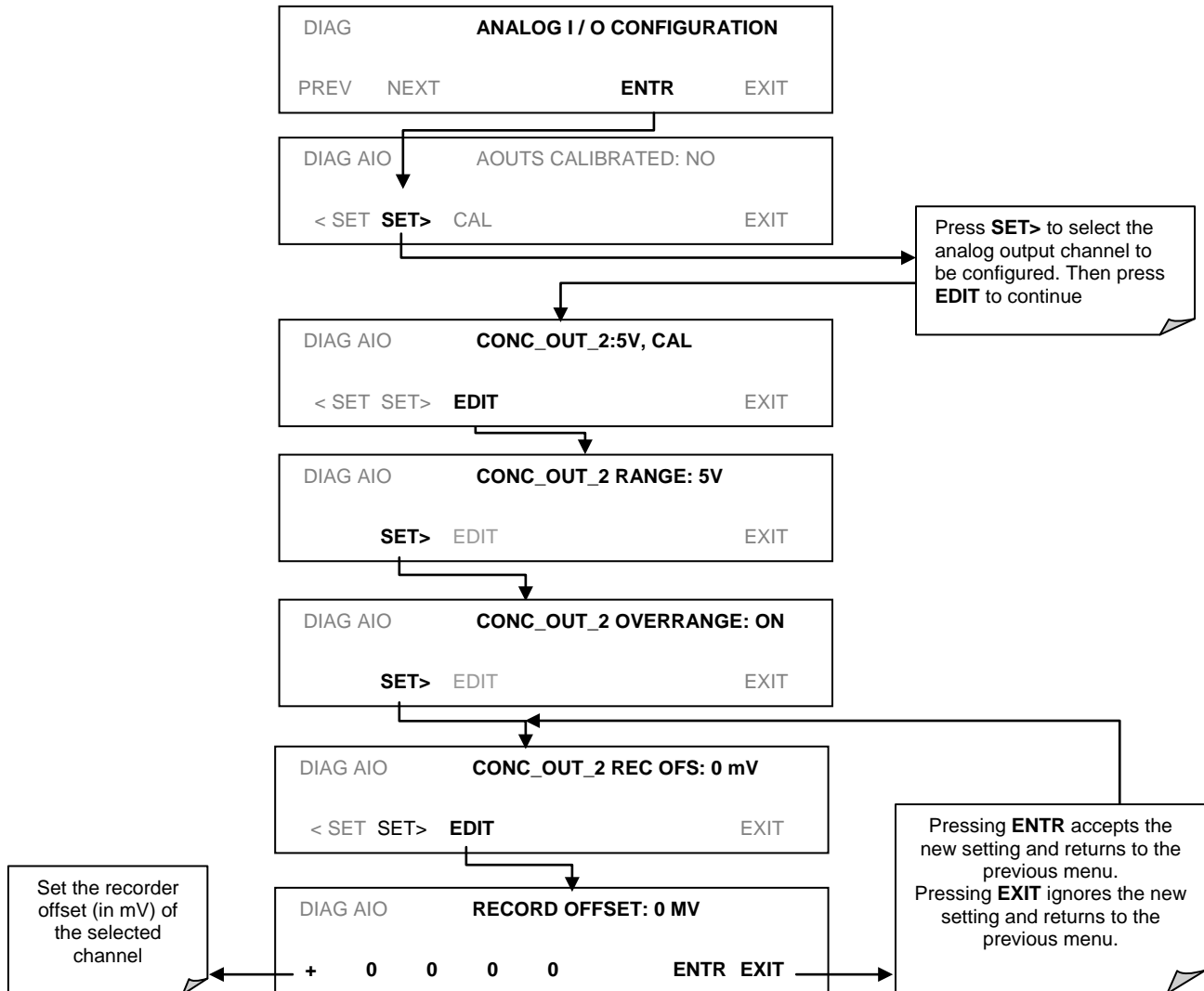


Figure 5-25: Analog Output – Offset Adjustment

### 5.9.3.5. CURRENT LOOP OUTPUT ADJUSTMENT

A current loop option is available and can be installed as a retrofit for each of the analog outputs of the analyzer (refer to Section 3.3.1.4). This option converts the DC voltage analog output to a current signal with 0-20 mA output current. The outputs can be scaled to any set of limits within that 0-20 mA range. However, most current loop applications call for either 2-20 mA or 4-20 mA range. All current loop outputs have a +5% over-range. Ranges with the lower limit set to more than 1 mA (e.g., 2-20 or 4-20 mA) also have a -5% under-range.

To switch an analog output from voltage to current loop after installing the current output printed circuit assembly, follow the instructions in Section 5.9.3.1 and select **CURR** from the list of options on the “Output Range” menu.

Adjusting the signal zero and span values of the current loop output is done by raising or lowering the voltage of the respective analog output. This proportionally raises or lowers the current produced by the current loop option.

Similar to the voltage calibration, the software allows this current adjustment to be made in 100, 10 or 1 count increments. Since the exact current increment per voltage count varies from output to output and from instrument to instrument, you will need to measure the change in the current with a current meter placed in series with the output circuit (refer to Figure 5-26).

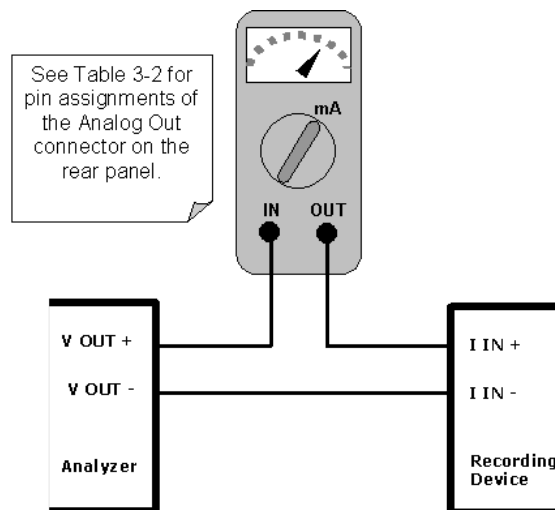


Figure 5-26: Setup for Calibrating Current Outputs



#### WARNING

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

To adjust the zero and span values of the current outputs, activate the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:

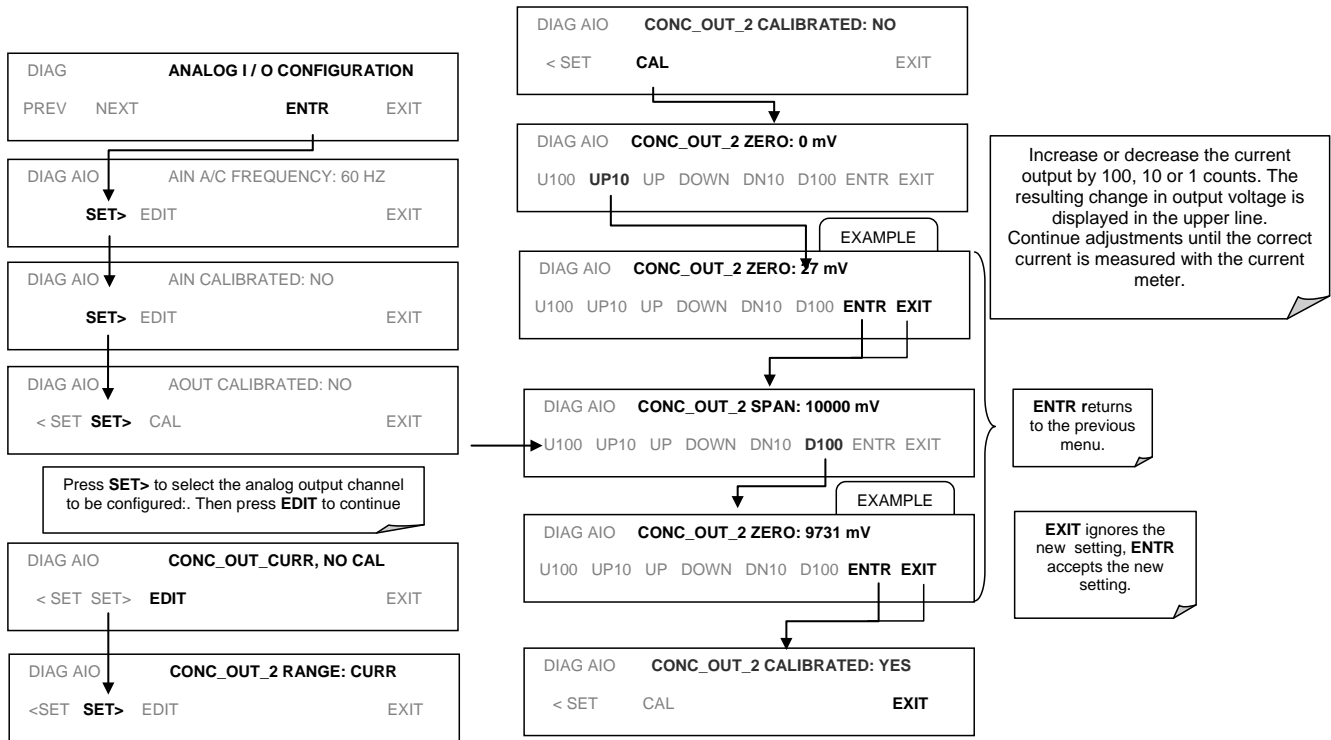


Figure 5-27: Analog Output – Zero and Span Value Adjustment for Current Outputs

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

Table 5-8: Current Loop Output Calibration with Resistor

FULL SCALE	VOLTAGE FOR 2-20 MA (MEASURED ACROSS RESISTOR)	VOLTAGE FOR 4-20 MA (MEASURED ACROSS RESISTOR)
0%	0.5 V	1.0 V
100%	5.0 V	5.0 V

### 5.9.3.6. AIN CALIBRATION

This is the sub-menu to conduct the analog input calibration. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies. Navigate to the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:

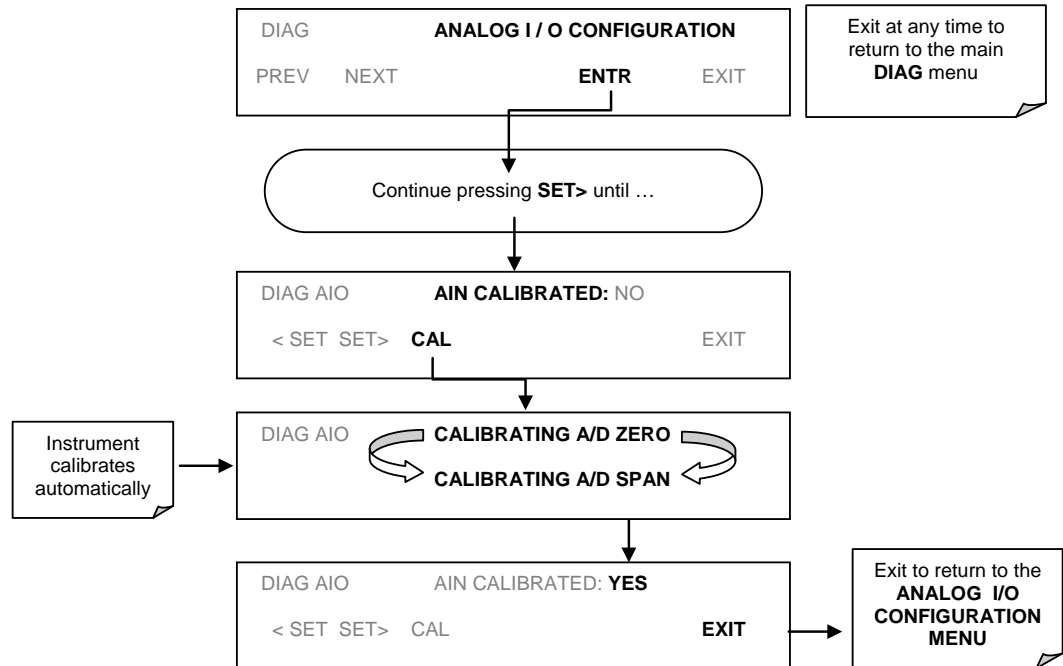


Figure 5-28: DIAG – Analog Output – AIN Calibration

### 5.9.3.7. ANALOG INPUTS (XIN1...XIN8) OPTION CONFIGURATION

To configure the analyzer's **optional analog inputs** define for each channel:

- gain (number of units represented by 1 volt)
- offset (volts)
- engineering units to be represented in volts (each press of the touchscreen button scrolls the list of alphanumeric characters from A-Z and 0-9)
- whether to display the channel in the Test functions

To adjust settings for the Analog Inputs option parameters press:

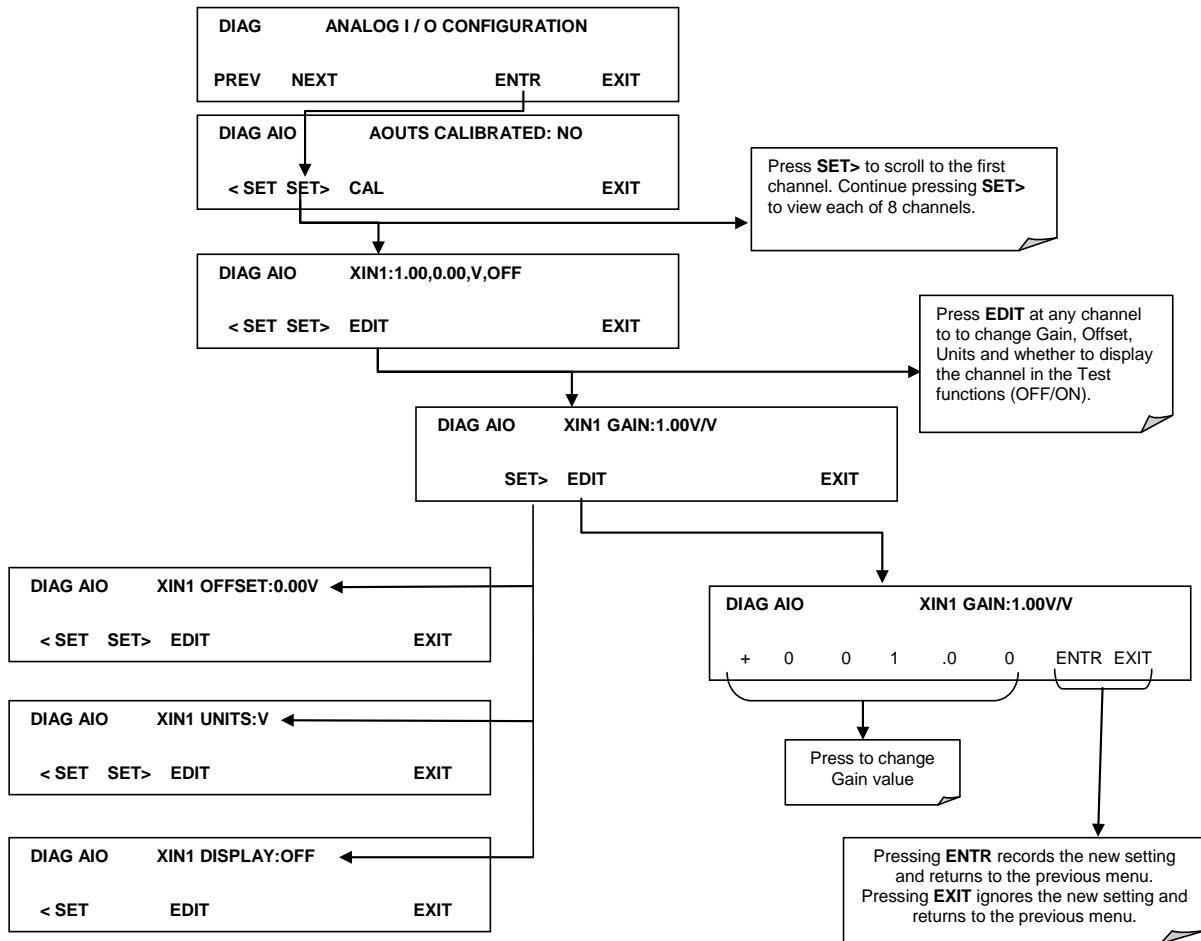


Figure 5-29. DIAG – Analog Inputs (Option) Configuration Menu

### 5.9.4. OPTIC TEST

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (refer to Figure 12-18). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board. To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air. The optic test should produce a PMT signal of about 2000±1000 mV.

Access the Optic Test from the DIAG Menu (refer to Figure 5-16), then press:

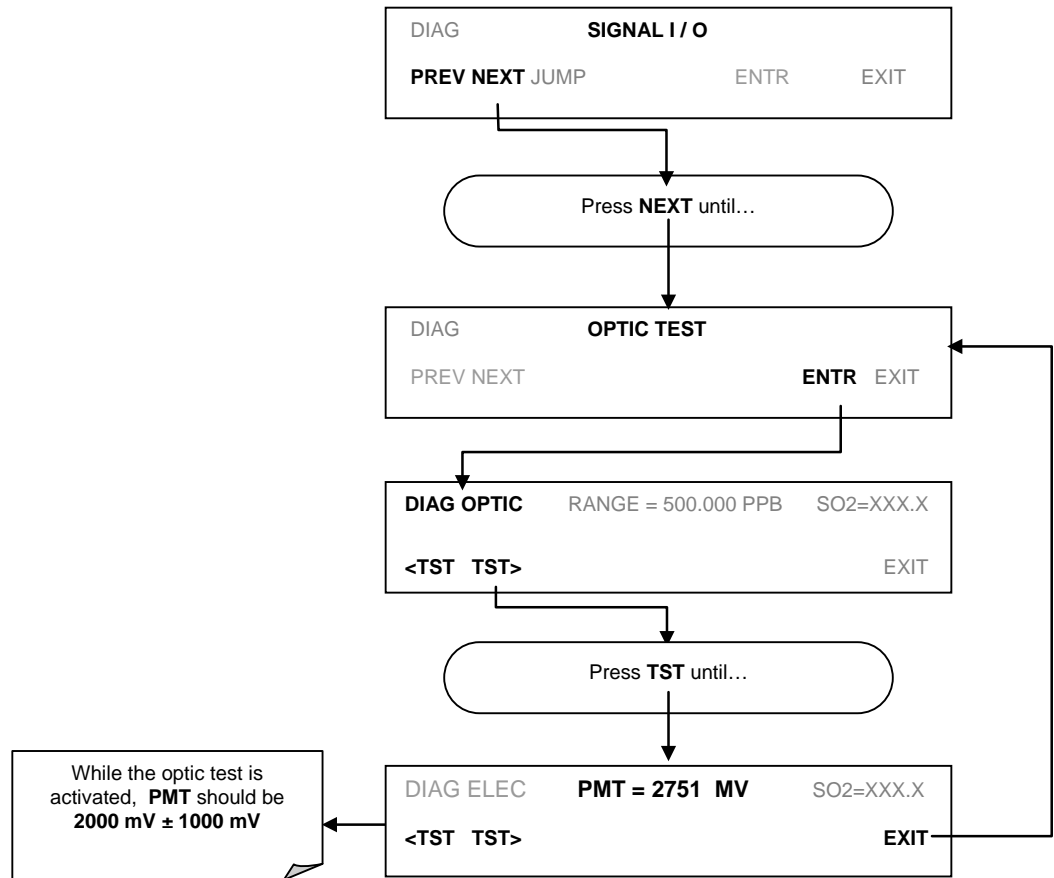


Figure 5-30: DIAG – Optic Test

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

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

### 5.9.5. ELECTRICAL TEST

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

Access the Electrical Test from the DIAG Menu (refer to Figure 5-16), then press:

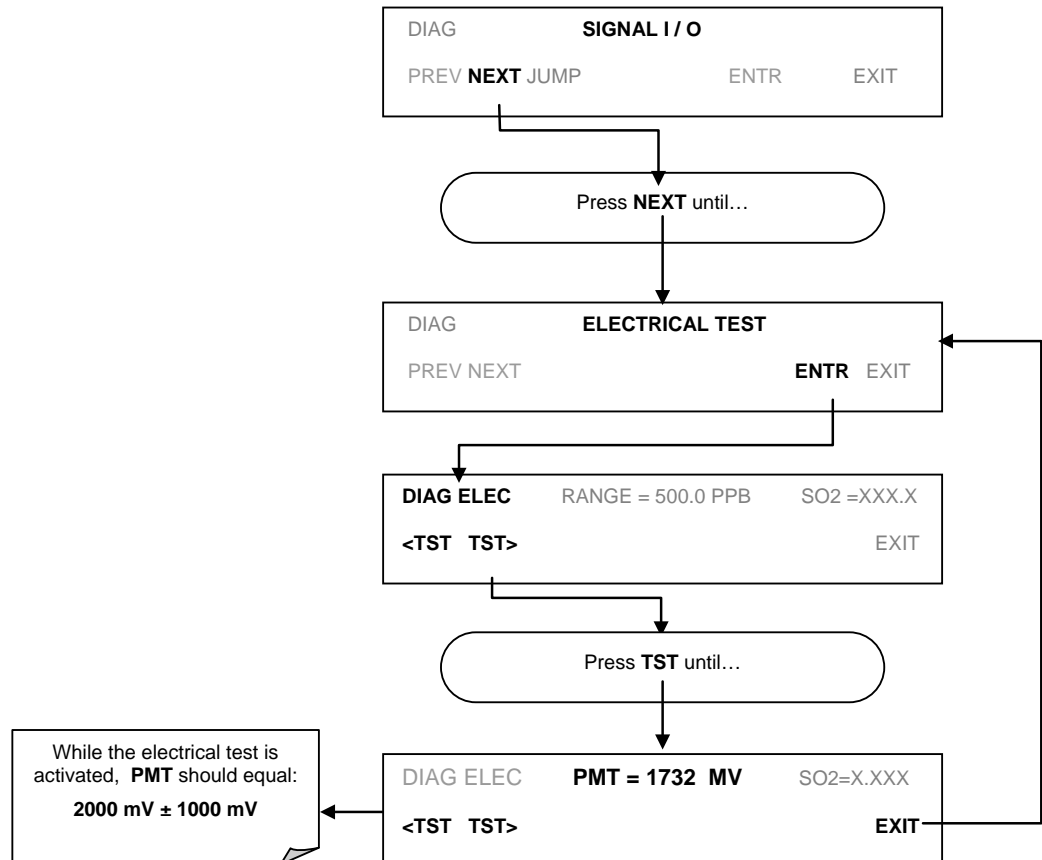


Figure 5-31: DIAG – Electrical Test



### 5.9.6. LAMP CALIBRATION

An important factor in accurately determining SO<sub>2</sub> concentration is the amount of UV light available to transform the SO<sub>2</sub> into SO<sub>2</sub>\* (refer to Section 12.1.1). The T100 compensates for variations in the intensity of the available UV light by adjusting the SO<sub>2</sub> concentration calculation using a ratio (**LAMP RATIO**) that results from dividing the current UV lamp (**UV LAMP**) intensity by a value stored in the CPU's memory (**LAMP\_CAL**). Both LAMP Ratio and UV Lamp are test functions viewable from the instruments front panel.

To cause the analyzer to measure and record a value for **LAMP\_CAL**, access the Signal I/O from the DIAG Menu (refer to Figure 5-16), then press:

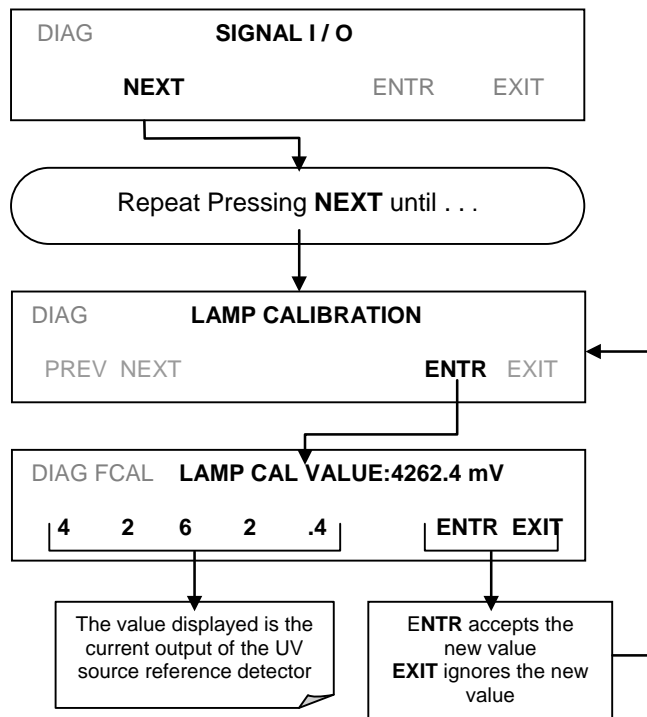


Figure 5-32: DIAG – Lamp Calibration

### 5.9.7. PRESSURE CALIBRATION

A sensor at the exit of the sample chamber continuously measures the pressure of the sample gas. This data is used to compensate the final SO<sub>2</sub> concentration calculation for changes in atmospheric pressure when the instrument's TPC feature is turned on (refer to Section 5.8, Table 5-2) and is stored in the CPU's memory as the test function **PRES** (also viewable via the front panel).

Ensure to use a barometer that measures actual barometric pressure.

To cause the analyzer to measure and record a value for **PRES**, access the Signal I/O from the DIAG Menu, SETUP>MORE>DIAG (refer to Figure 5-16), then press:

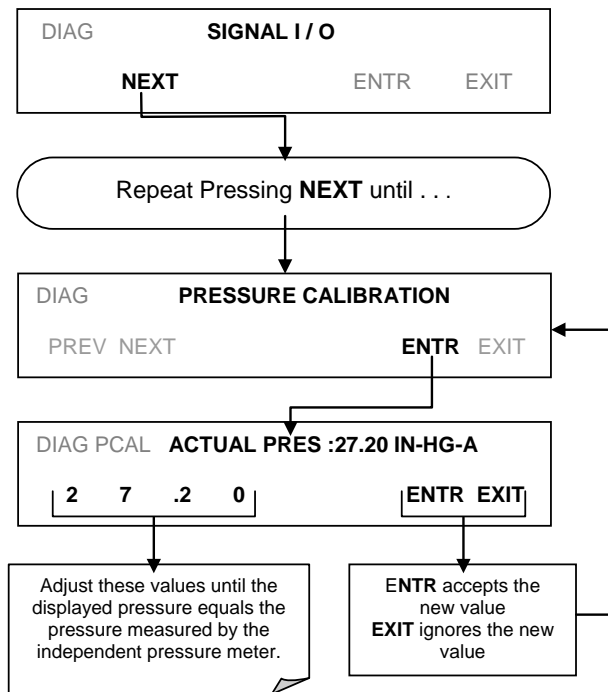


Figure 5-33: DIAG – Pressure Calibration

### 5.9.8. FLOW CALIBRATION

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

To carry out this adjustment, connect an external, sufficiently accurate flow meter to the SAMPLE inlet (refer to Section 10.3.7 for more details).

Once the flow meter is attached and is measuring actual gas flow, access the Signal I/O from the DIAG Menu, SETUP>MORE>DIAG (refer to Figure 5-16), then press:

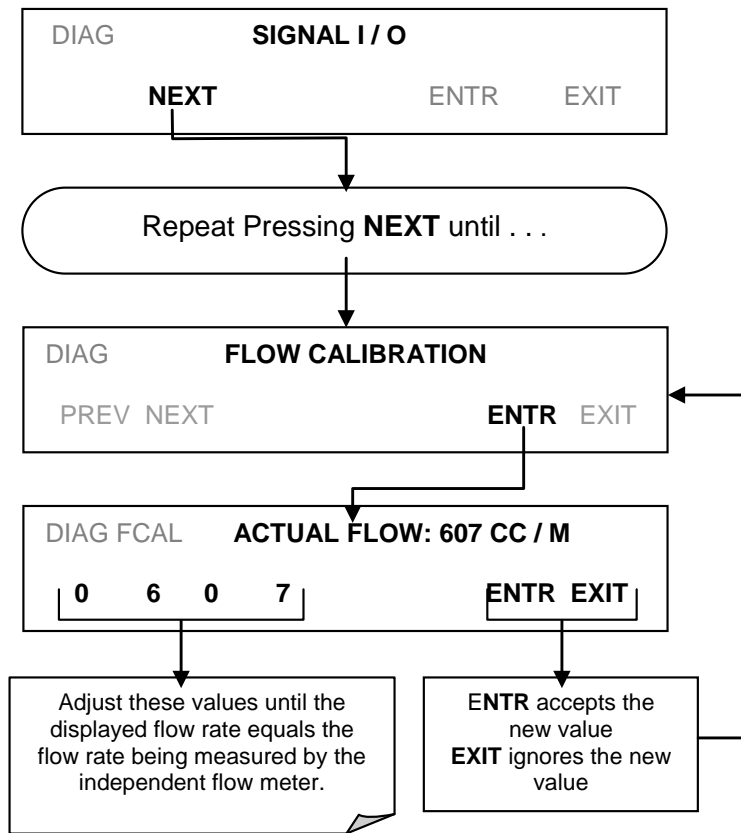


Figure 5-34: DIAG – Flow Calibration

### 5.9.9. TEST CHANNEL OUTPUT

When activated, output channel **A3** can be used in the standard configuration to report one of the test functions viewable from the SAMPLE mode display.

To activate the **A3** channel and select a test function, access the Signal I/O from the DIAG Menu, SETUP>MORE.DIAG (refer to Figure 5-16), then press:

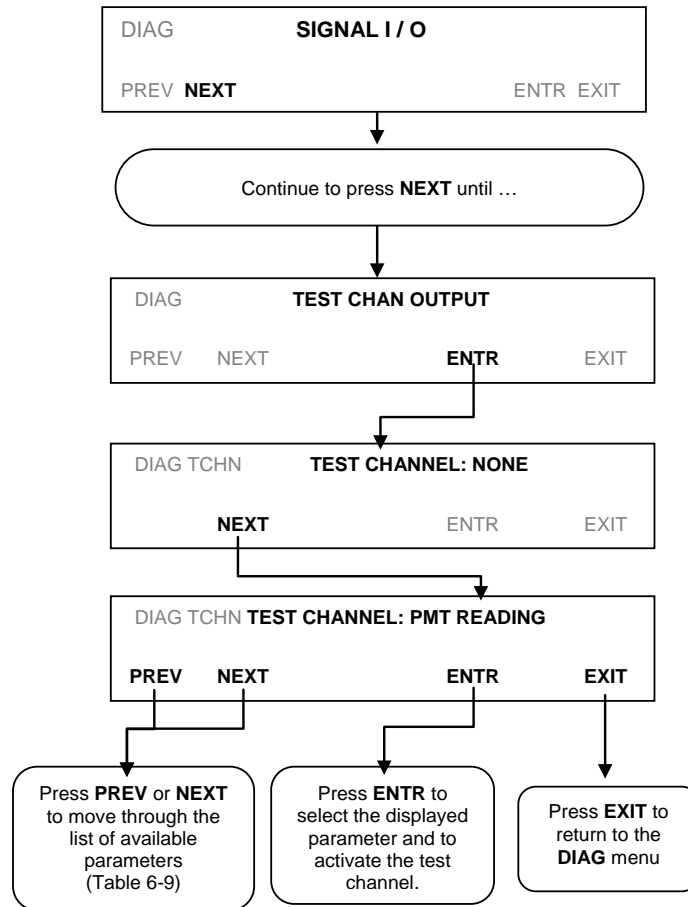


Figure 5-35: DIAG – Test Channel Output

**Table 5-9: Test Parameters Available for Analog Output A3 (standard configuration)**

Test Channel	Test parameter range
NONE	Test channel is turned off
PMT READING	0-5000 mV
UV READING	0-5000 mV
SAMPLE PRESSURE	0-40 in-Hg-A
SAMPLE FLOW	0-1000 cm <sup>3</sup> /min
RCELL TEMP	0-70° C
CHASSIS TEMP	0-70° C
IZS TEMP	0-70° C
PMT TEMP	0-50° C
HVPS VOLTAGE	0-5000 V

Once a TEST function is selected, the instrument begins to report a signal on the **A3** output and adds **TEST** to the list of test functions viewable on the display (just before the **TIME** test function).

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## 6. COMMUNICATIONS SETUP AND OPERATION

This instrument rear panel connections include an Ethernet port, a USB port (option) and two serial communications ports (labeled **RS232**, which is the COM1 port, and **COM2**) located on the rear panel (refer to Figure 3-4). These ports give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal.

This section provides pertinent information regarding communication equipment, describes the instrument's communications modes, presents configuration instructions for the communications ports, and provides instructions for their use, including communications protocol. Data acquisition is presented in Section 7.

### 6.1. DATA TERMINAL / COMMUNICATION EQUIPMENT (DTE DCE)

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

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

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

### 6.2. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

Use the `SETUP>MORE>COMM` menu to configure COM1 (labeled **RS232** on instrument rear panel) and/or COM2 (labeled **COM2** on instrument rear panel) for communication modes, baud rate and/or port testing for correct connection. If using a USB option communication connection, setup requires configuring the COM2 baud rate (Section 6.2.2).

### 6.2.1. COMMUNICATION MODES

Either of the analyzer’s serial ports (**RS232** or **COM2** on rear panel) can be configured to operate in a number of different modes, which are described in .

**Table 6-1: COMM Port Communication Modes**

MODE <sup>1</sup>	ID	DESCRIPTION
<b>QUIET</b>	<b>1</b>	Quiet mode suppresses any feedback from the analyzer (DAS reports, and warning messages) to the remote device and is typically used when the port is communicating with a computer program such as APICOM. Such feedback is still available but a command must be issued to receive them.
<b>COMPUTER</b>	<b>2</b>	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer program, such as APICOM.
<b>HESSEN PROTOCOL</b>	<b>16</b>	The Hessen communications protocol is used in some European countries. Teledyne API’s part number 02252 contains more information on this protocol.
<b>E, 7, 1</b>	<b>2048</b>	Allows the <b>COMM</b> port settings to be set between either No parity; 8 data bits; 1 stop bit (ON/OFF) to Even parity; 7 data bits; 1 stop bit (ON/OFF)
<b>RS-485</b>	<b>1024</b>	Configures the <b>COM2</b> Port for RS-485 communication. RS-485 mode has precedence over Multidrop mode if both are enabled. When the COM2 port is configured for RS-485 communication, the rear panel USB port is disabled.
<b>SECURITY</b>	<b>4</b>	When enabled, the serial port requires a password before it will respond. The only command that is active is the help screen (? CR).
<b>MULTIDROP PROTOCOL</b>	<b>32</b>	Multidrop protocol allows a multi-instrument configuration on a single communications channel. Multidrop requires the use of instrument IDs.
<b>ENABLE MODEM</b>	<b>64</b>	Enables sending a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
<b>ERROR CHECKING<sup>2</sup></b>	<b>128</b>	Fixes certain types of parity errors at certain Hessen protocol installations.
<b>XON/XOFF HANDSHAKE<sup>2</sup></b>	<b>256</b>	Disables XON/XOFF data flow control also known as software handshaking.
<b>HARDWARE HANDSHAKE</b>	<b>8</b>	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.
<b>HARDWARE FIFO<sup>2</sup></b>	<b>512</b>	Improves data transfer rate when one of the COMM ports.
<b>COMMAND PROMPT</b>	<b>4096</b>	Enables a command prompt when in terminal mode.
<sup>1</sup> Modes are listed in the order in which they appear in the <b>SETUP → MORE → COMM → COM[1 OR 2] → MODE</b> menu <sup>2</sup> The default setting for this feature is <b>ON</b> . Do not disable unless instructed to by Teledyne API’s Technical Support personnel.		



To turn on or off the communication modes for either COM1 or COM2, access the **SETUP>MORE>[COM1 or COM2]** menu and at the **COM1[2] Mode** menu press **EDIT**.

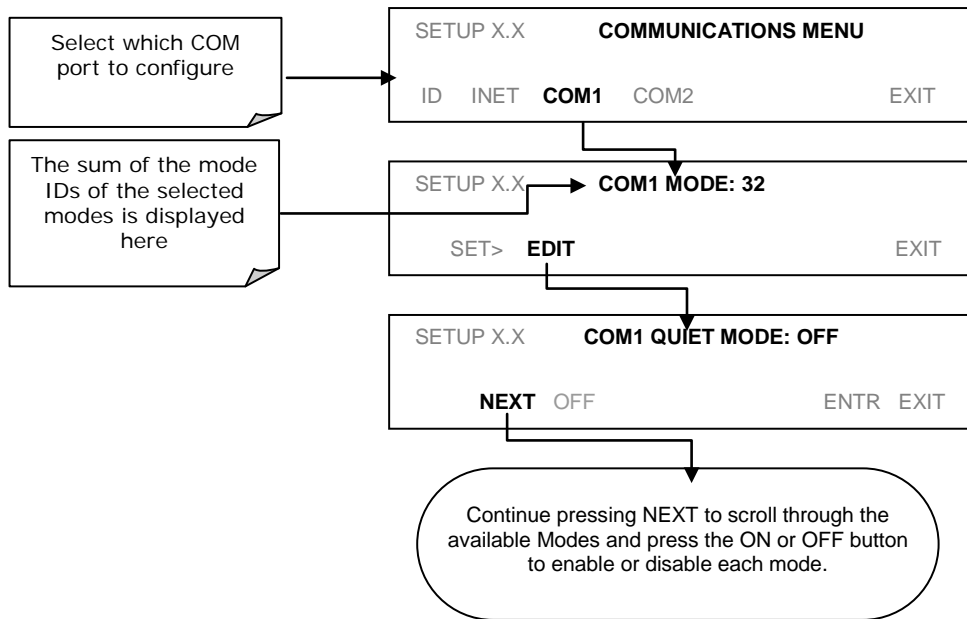


Figure 6-1: COMM – Communication Modes Setup

### 6.2.2. COMM PORT BAUD RATE

To select the baud rate of either COMM Port, go to **SETUP>MORE>COMM** and select either **COM1** or **COM2** as follows (use **COM2** to view/match your personal computer baud rate when using the USB port, Section 6.5.3):

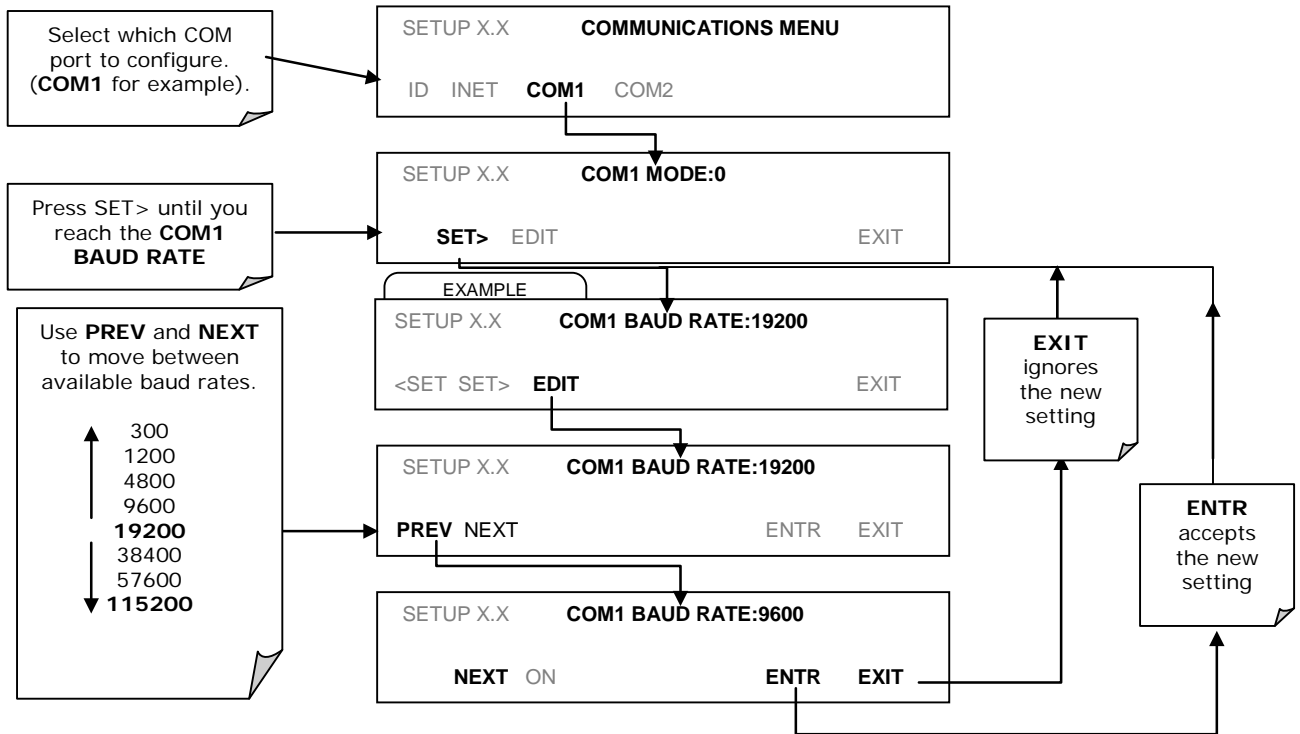


Figure 6-2: COMM – COMM Port Baud Rate

### 6.2.3. 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 COM port. While the test is running, the red LED on the rear panel of the analyzer should flicker.

To initiate the test press, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:

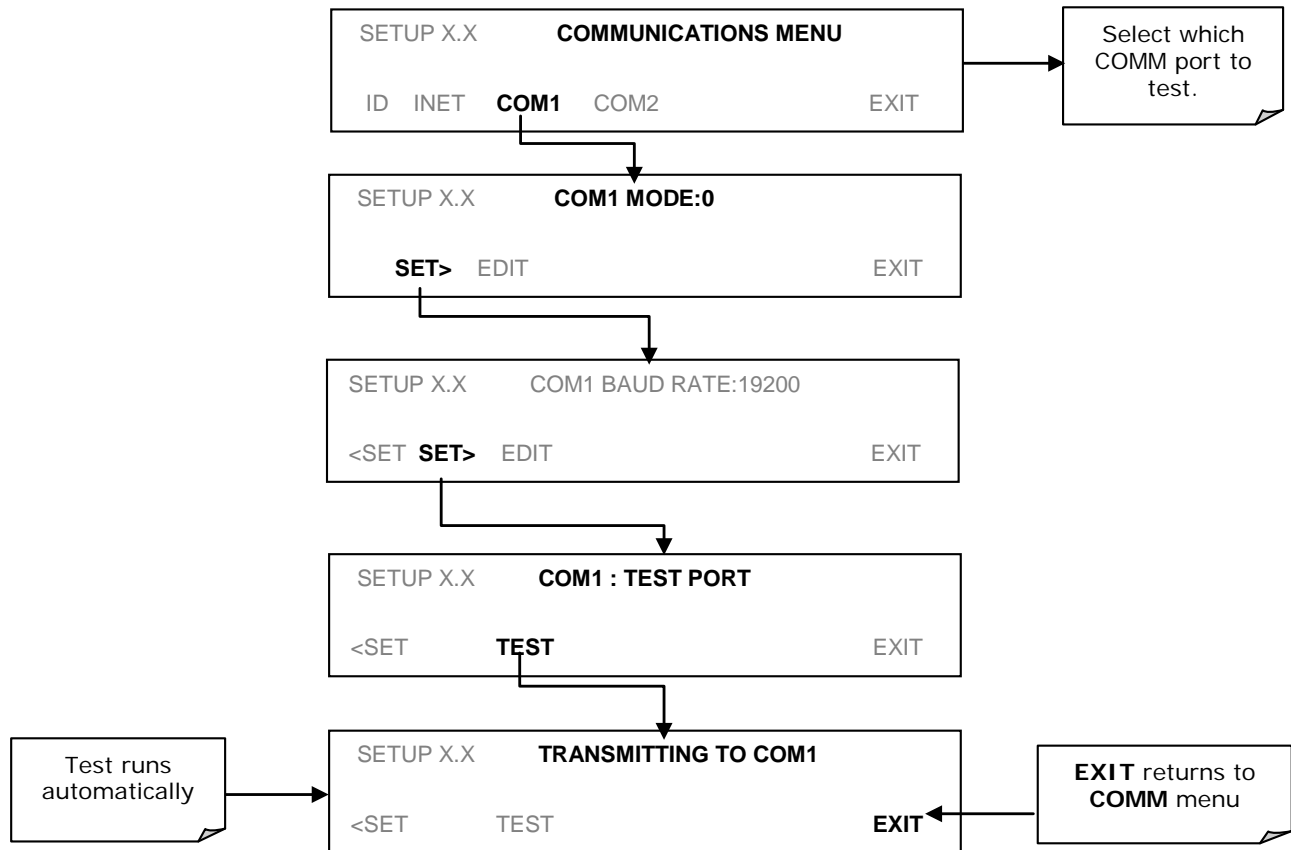


Figure 6-3: COMM – COM1 Test Port

### 6.3. RS-232

The **RS232** and **COM2** communications (COMM) ports operate on the RS-232 protocol (default configuration). Possible configurations for these two COMM ports are summarized as follows:

- **RS232** port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section 3.3.1.8.
- **COM2** port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

Note that when the rear panel **COM2** port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, **COM2** port cannot be used except for multidrop).

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

To configure the analyzer's communication ports, use the SETUP>MORE>COMM menu. Refer to Section 5.7 for initial setup, and to Section 6.2 for additional configuration information.

## 6.4. RS-485 (OPTION)

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

## 6.5. ETHERNET

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

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

**Table 6-2: Ethernet Status Indicators**

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

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server (Section 6.5.2). 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 6.5.1 below details how to configure the instrument with a static IP address.

### 6.5.1. CONFIGURING ETHERNET COMMUNICATION MANUALLY (STATIC IP ADDRESS)

1. Connect a cable from the analyzer's Ethernet port to a Local Area Network (LAN) or Internet port.
2. From the analyzer's front panel touchscreen, access the Communications Menu (SETUP>MORE>COMM as shown in Figure 5-13).
3. Follow the setup sequence as shown in Figure 6-4, and edit the Instrument and Gateway IP addresses and Subnet Mask to the desired settings.
4. From the computer, enter the same information through an application such as HyperTerminal.

Table 6-3 shows the default Ethernet configuration settings.

**Table 6-3: LAN/Internet Default Configuration Properties**

PROPERTY	DEFAULT STATE	DESCRIPTION
<b>DHCP</b>	ON	This displays whether the DHCP is turned ON or OFF. Press EDIT and toggle ON for automatic configuration after first consulting network administrator. (
<b>INSTRUMENT IP ADDRESS</b>		This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the analyzer itself.
<b>GATEWAY IP ADDRESS</b>	0.0.0.0	Can only be edited when DHCP is set to OFF. 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.
<b>SUBNET MASK</b>	0.0.0.0	Can only be edited when DHCP is set to OFF. Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) 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 to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
<b>TCP PORT<sup>1</sup></b>	3000	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
<b>HOST NAME</b>	T100	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. To change, see Section 6.5.2.1.
<sup>1</sup> Do not change the setting for this property unless instructed to by Teledyne API's Technical Support personnel.		

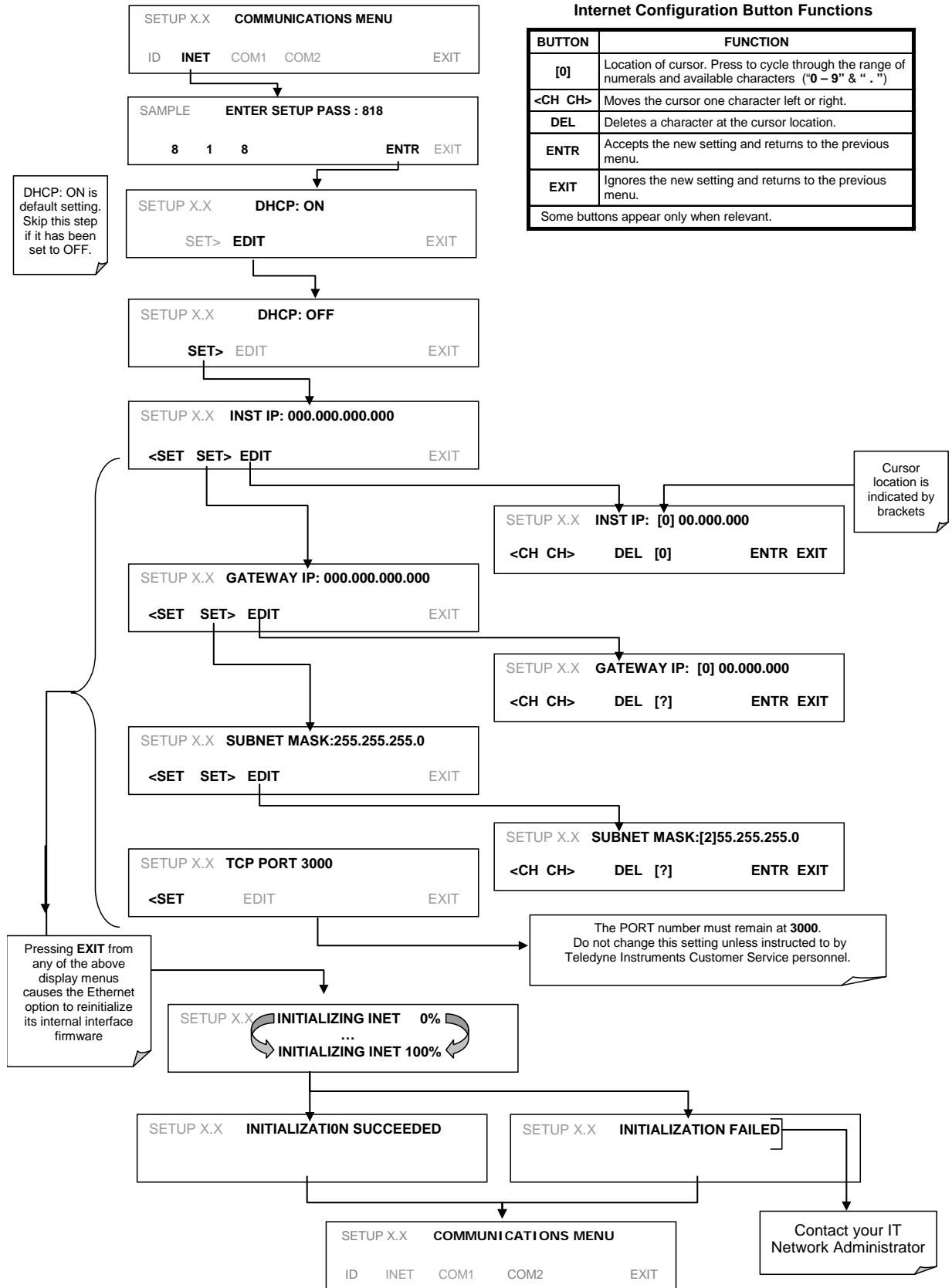


Figure 6-4: COMM – LAN / Internet Manual Configuration

### 6.5.2. CONFIGURING ETHERNET COMMUNICATION USING DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP)

1. Consult with your network administrator to affirm that your network server is running DHCP.
2. Access the Communications Menu as shown in Figure 5-13.
3. Follow the setup sequence as shown in Figure 6-5.

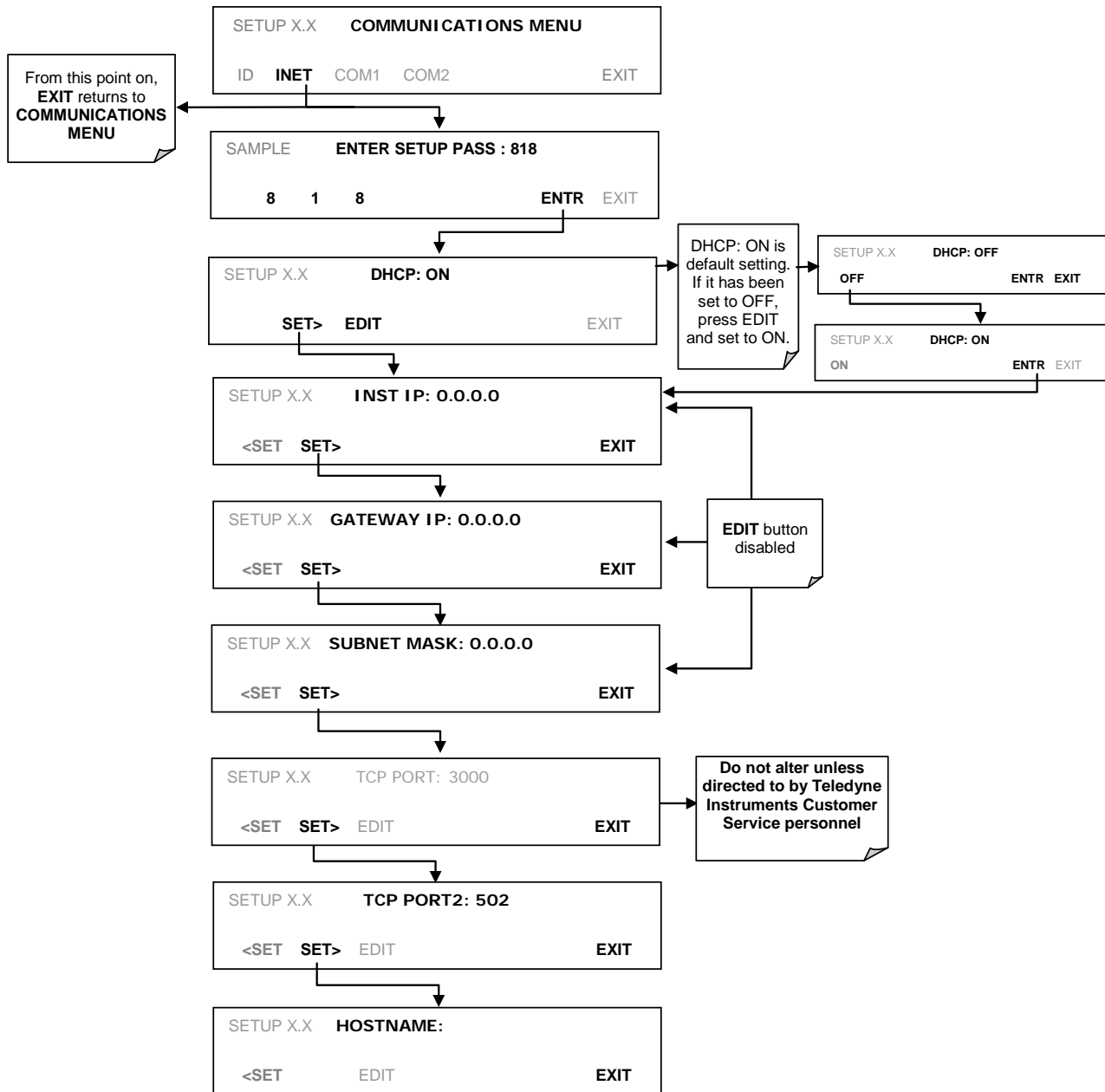


Figure 6-5: COMM – LAN / Internet Automatic Configuration

6.5.2.1. CHANGING THE ANALYZER'S HOSTNAME

The **HOSTNAME** is the name by which the analyzer appears on your network. The typical default name for all Teledyne API's T100 analyzers is **100** but could be **0**. To change this name (particularly if you have more than one T100 analyzer on your network), access the **COMMUNICATIONS** Menu (refer to Figure 5-13), then press:

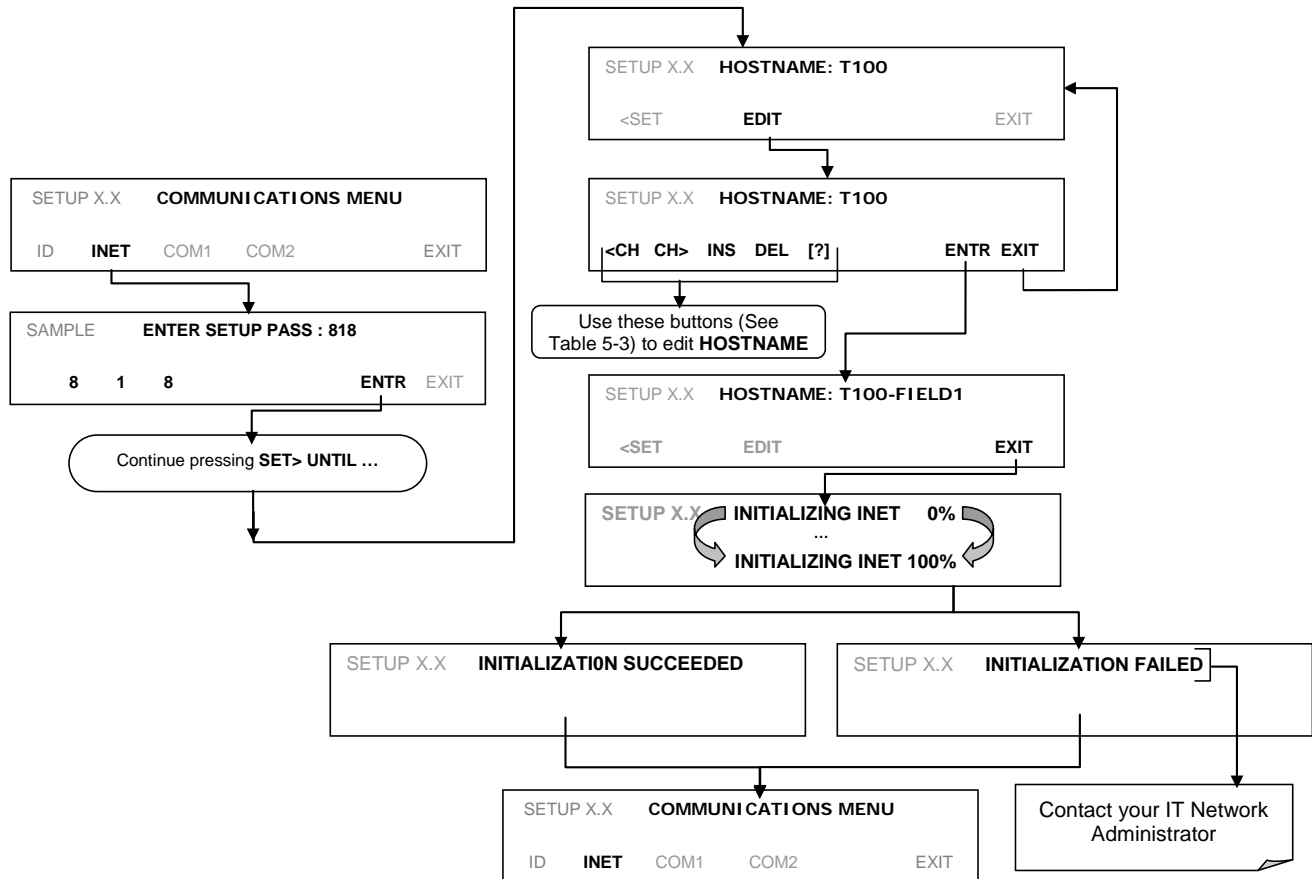


Figure 6-6: COMM – Change Hostname

Table 6-4: Hostname Editing Button Functions

Button	Function
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this button 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.

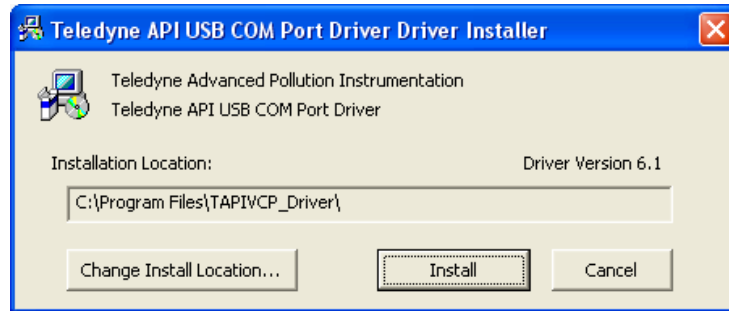
Buttons only appear when applicable.



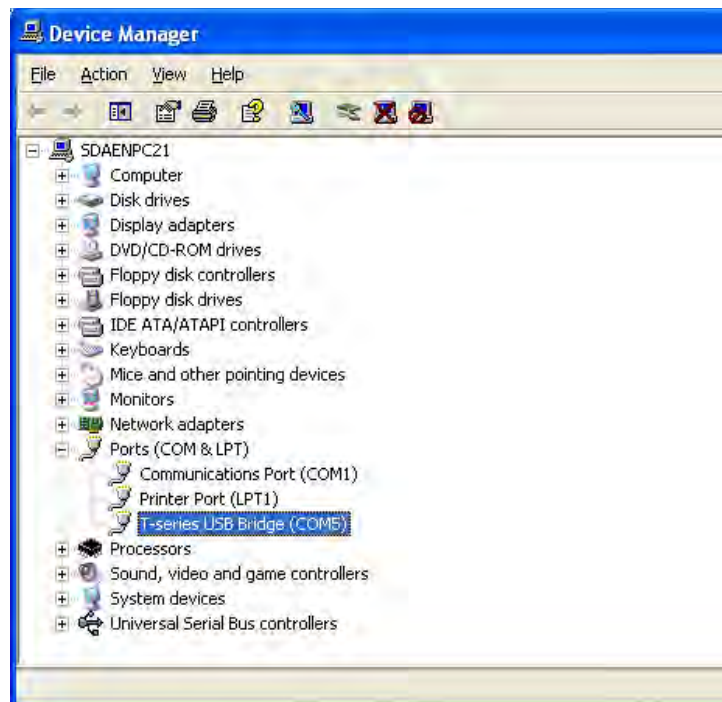
### 6.5.3. USB PORT FOR REMOTE ACCESS

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

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



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

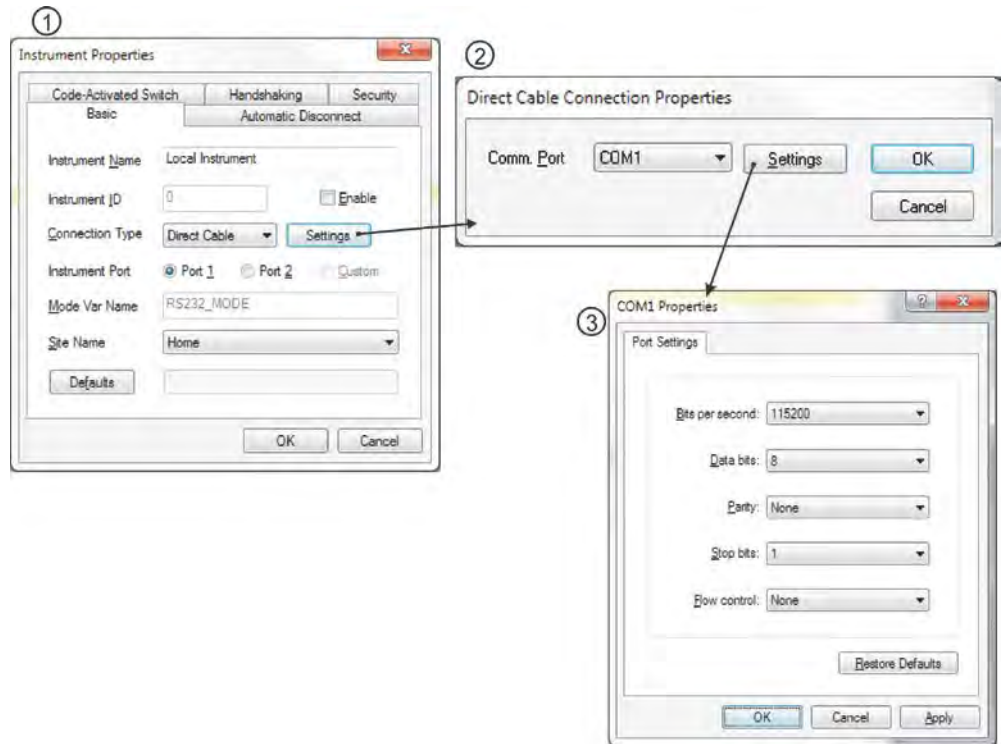


Refer to the Quick Start (*Direct Cable Connection*) section of the Teledyne APIcom Manual, PN 07463.

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

Baud Rate: 115200			
COM2 Mode Settings:			
Quiet Mode	ON	SECURITY MODE	OFF
Computer Mode	ON	MULTIDROP MODE	OFF
MODBUS RTU	OFF	ENABLE MODEM	OFF
MODBUS ASCII	OFF	ERROR CHECKING	ON
E,8,1 MODE	OFF	XON/XOFF HANDSHAKE	OFF
E,7,1 MODE	OFF	HARDWARE HANDSHAKE	OFF
RS-485 MODE	OFF	HARDWARE FIFO	ON
		COMMAND PROMPT	OFF

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



**Note**

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

## 6.6. COMMUNICATIONS PROTOCOLS

### 6.6.1. MODBUS

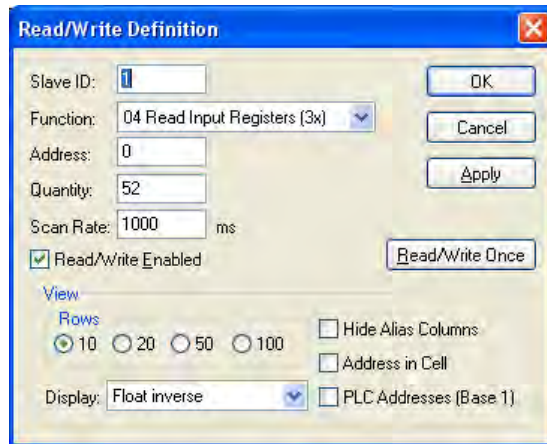
The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to [www.modbus.org](http://www.modbus.org) for MODBUS communication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

#### Minimum Requirements

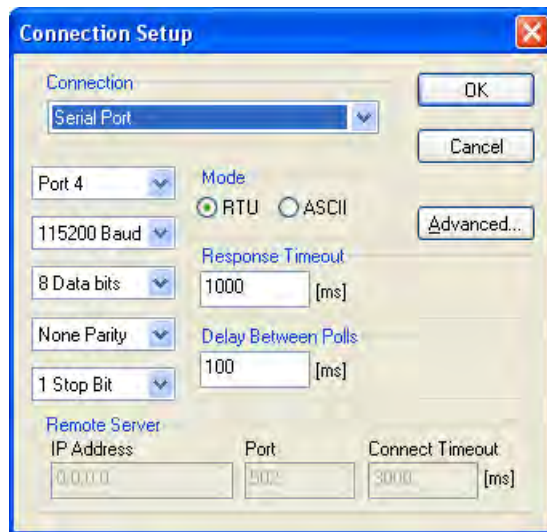
- Instrument firmware with MODBUS capabilities installed.
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see [www.modbustools.com](http://www.modbustools.com))
- Personal computer
- Communications cable (Ethernet or USB or RS232)
- Possibly a null modem adapter or cable

MODBUS Setup:	
Set Com Mode parameters	
Comm	<p>Ethernet: Using the front panel menu, go to SETUP – MORE – COMM – INET; scroll through the INET submenu until you reach TCP PORT 2 (the standard setting is 502), then continue to TCP PORT 2 MODBUS TCP/IP; press EDIT and toggle the menu button to change the setting to ON, then press ENTR. (Change Machine ID if needed: see “Slave ID”).</p> <p>USB/RS232: Using the front panel menu, go to SETUP – MORE – COMM – COM2 – EDIT; scroll through the COM2 EDIT submenu until the display shows COM2 MODBUS RTU: OFF (press OFF to change the setting to ON. Scroll NEXT to COM2 MODBUS ASCII and ensure it is set to OFF. Press ENTR to keep the new settings. (If RTU is not available with your communications equipment, set the COM2 MODBUS ASCII setting to ON and ensure that COM2 MODBUS RTU is set to OFF. Press ENTR to keep the new settings).</p>
Slave ID	A MODBUS slave ID must be set for each instrument. Valid slave ID's are in the range of 1 to 247. If your analyzer is connected to a serial network (i.e., RS-485), a unique Slave ID must be assigned to each instrument. To set the slave ID for the instrument, go to SETUP – MORE – COMM – ID. The default MACHINE ID is the same as the model number. Toggle the menu buttons to change the ID.
Reboot analyzer	For the settings to take effect, power down the analyzer, wait 5 seconds, and power up the analyzer.
Make appropriate cable connections	<p>Connect your analyzer either:</p> <ul style="list-style-type: none"> <li>• via its Ethernet or USB port to a PC (this may require a USB-to-RS232 adapter for your PC; if so, also install the software driver from the CD supplied with the adapter, and reboot the computer if required), or</li> <li>• via its COM2 port to a null modem (this may require a null modem adapter or cable).</li> </ul>
Specify MODBUS software settings (examples used here are for MODBUS Poll software)	<ol style="list-style-type: none"> <li>1. Click Setup / [Read / Write Definition] /. <ol style="list-style-type: none"> <li>a. In the Read/Write Definition window (see example that follows) select a <b>Function</b> (what you wish to read from the analyzer).</li> <li>b. Input <b>Quantity</b> (based on your firmware's register map).</li> <li>c. In the View section of the Read/Write Definition window select a <b>Display</b> (typically Float Inverse).</li> <li>d. Click <b>OK</b>.</li> </ol> </li> <li>2. Next, click Connection/Connect. <ol style="list-style-type: none"> <li>a. In the Connection Setup window (see example that follows), select the options based on your computer.</li> <li>b. Press <b>OK</b>.</li> </ol> </li> </ol>
Read the Modbus Poll Register	Use the Register Map to find the test parameter names for the values displayed (see example that follows). If desired, assign an alias for each.

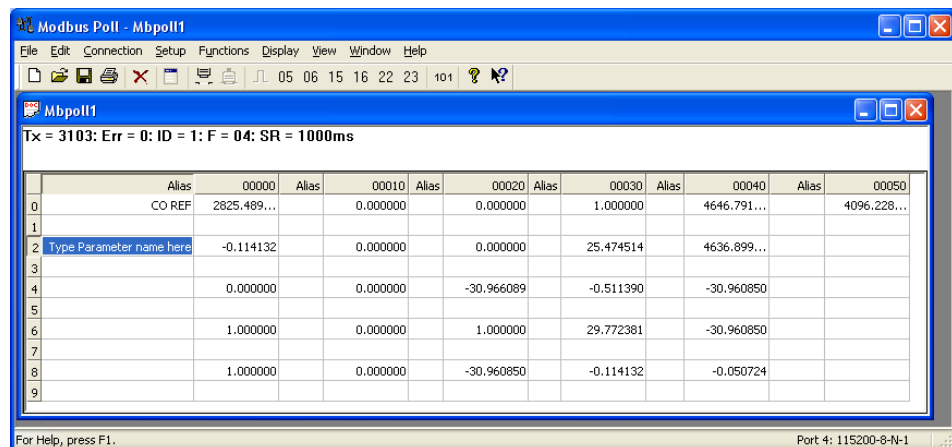
Example Read/Write Definition window:



Example Connection Setup window:



Example MODBUS Poll window:



## 6.6.2. HESSEN

The Hessen protocol is a Multidrop protocol, in which several remote instruments are connected via a common communications channel to a host computer. The remote instruments are regarded as slaves of the host computer. The remote instruments are unaware that they are connected to a Multidrop bus and never initiate Hessen protocol messages. They only respond to commands from the host computer and only when they receive a command containing their own unique ID number.

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

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

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

### 6.6.2.1. HESSEN COMM PORT CONFIGURATION

Hessen protocol requires the communication parameters of the T100's COMM ports to be set differently than the standard configuration as shown in the table below.

**Table 6-5: RS-232 Communication Parameters for Hessen Protocol**

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

To change the rest of the COMM port parameters and modes, refer to Section 6.

To change the baud rate of the T100's COMM ports, refer to Section 6.2.2.

#### IMPORTANT

#### IMPACT ON READINGS OR DATA

**Ensure that the communication parameters of the host computer are also properly set.**

#### Note

**The instrument software has a 200 ms latency before it responds to commands issued by the host computer. This latency should present no problems, but you should be aware of it and not issue commands to the instrument too quickly.**

### 6.6.2.2. ACTIVATING HESSEN PROTOCOL

The first step in configuring the T100 to operate over a Hessen protocol network is to activate the Hessen mode for COMM ports and configure the communication parameters for the port(s) appropriately. Access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:

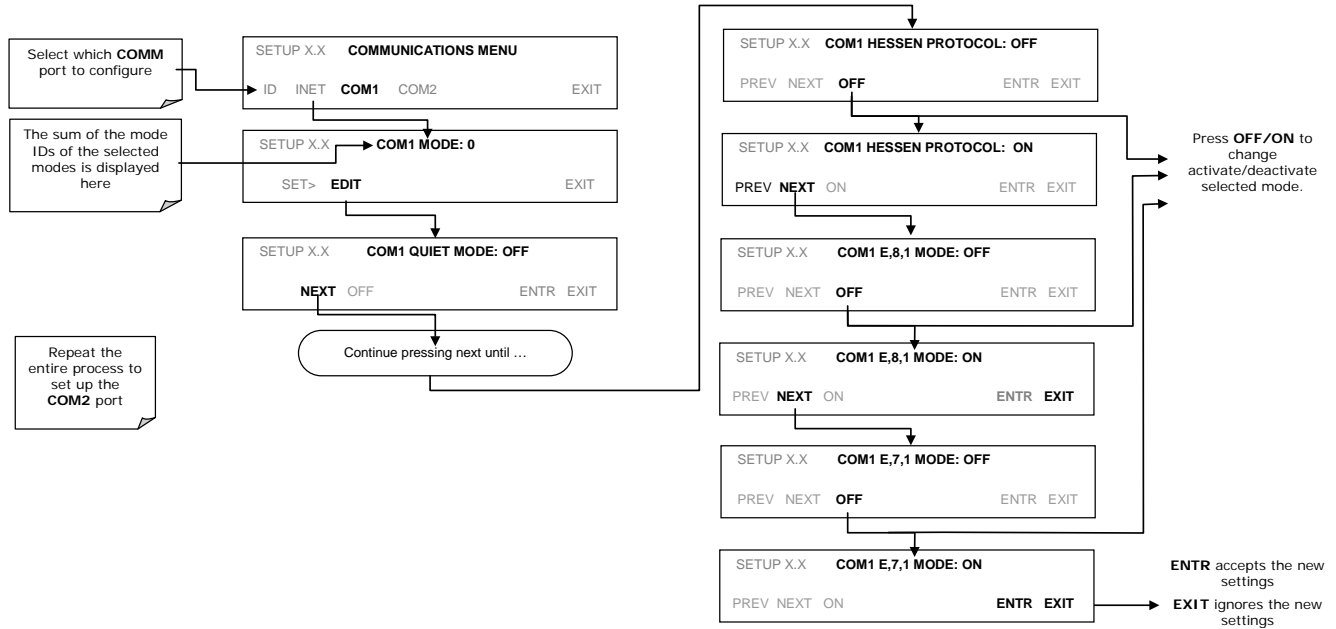


Figure 6-7: COMM – Activating Hessen Protocol

### 6.6.2.3. SELECTING A HESSEN PROTOCOL TYPE

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

To select a Hessen Protocol Type, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:

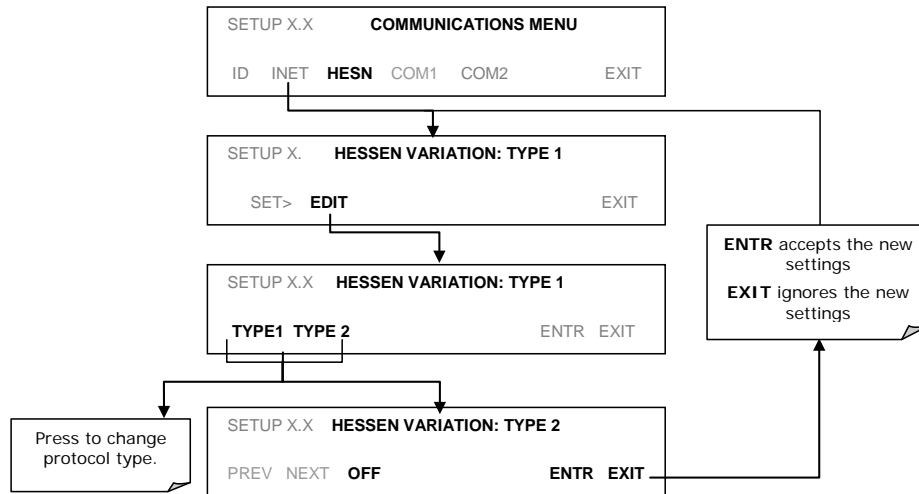


Figure 6-8: COMM – Select Hessen Protocol Type

#### Note

While Hessen Protocol Mode can be activated independently for RS-232 and COM2, the TYPE selection affects both Ports.

6.6.2.4. SETTING THE HESSEN PROTOCOL RESPONSE MODE

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

Table 6-6: T100 Hessen Protocol Response Modes

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

To Select a Hessen response mode, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:

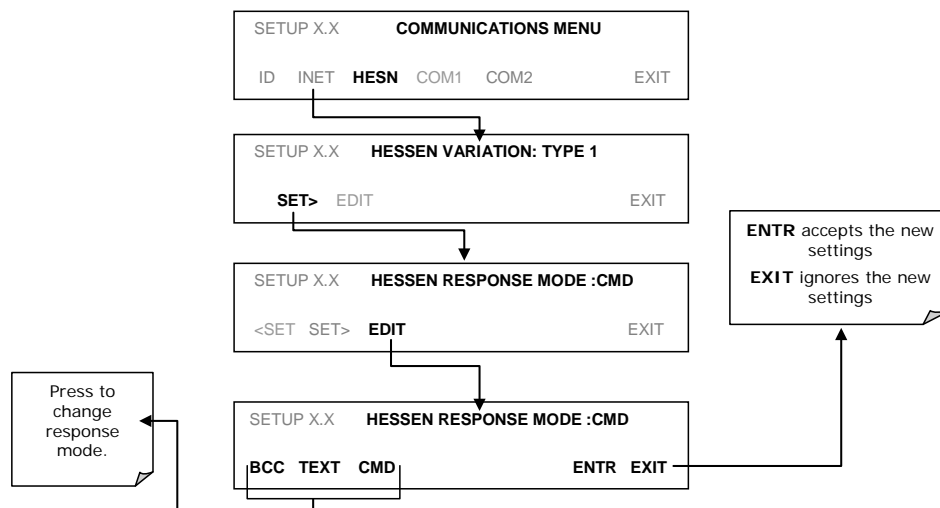


Figure 6-9: COMM – Select Hessen Protocol Response Mode



### 6.6.2.5. HESSEN PROTOCOL GAS ID

The T100 analyzer is a single gas instrument that measures SO<sub>2</sub>. As such, its default gas ID has already been set to **110**. There is no need to change this setting.

### 6.6.2.6. SETTING HESSEN PROTOCOL STATUS FLAGS

Teledyne API's implementation of Hessen protocols includes a set of status bits that the instrument includes in responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag. The default settings for these bit/flags are listed in Table 6-7:

**Table 6-7: Default Hessen Status Bit Assignments**

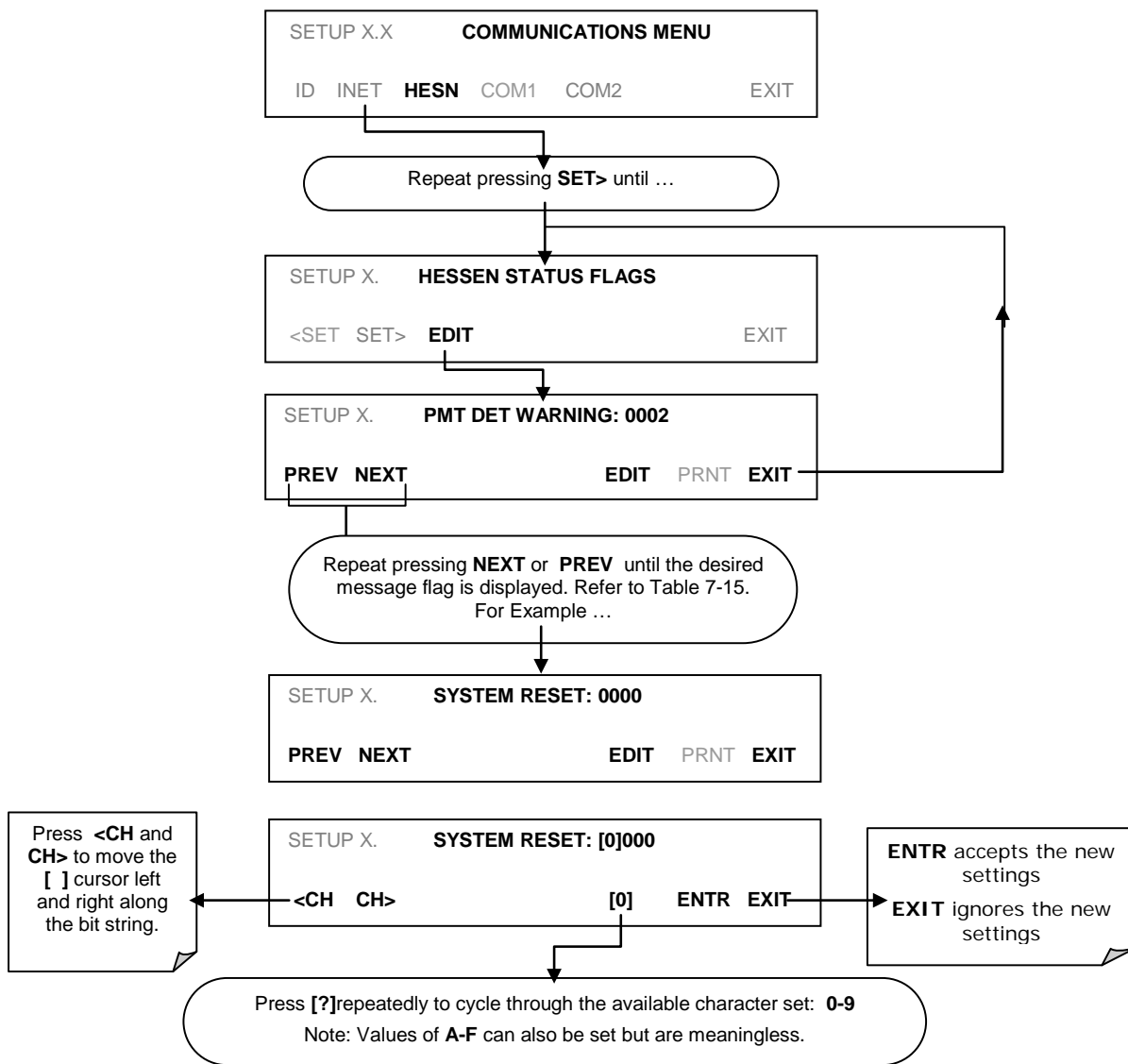
STATUS FLAG NAME	DEFAULT BIT ASSIGNMENT
<b>WARNING FLAGS</b>	
SAMPLE FLOW WARNING	0001
PMT DET WARNING	0002
UV LAMP WARNING	0002
HVPS WARNING	0004
DARK CAL WARNING	0008
RCELL TEMP WARNING	0010
IZS TEMP WARNING	0020
PMT TEMP WARNING	0040
INVALID CONC	0080
<b>OPERATIONAL FLAGS</b>	
In Manual Calibration Mode	0200
In Zero Calibration Mode	0400
In Span Calibration Mode	0800
<b>UNITS OF MEASURE FLAGS</b>	
UGM	0000
MGM	2000
PPB	4000
PPM	6000
<b>SPARE/UNUSED BITS</b>	100. 8000
<b>UNASSIGNED FLAGS</b>	
Box Temp Warning	MP Calibration
Sample Press Warning	Analog Cal Warning
System Reset	Cannot Dyn Zero
Rear Board Not Detected	Cannot Dyn Span
Relay Board Warning	Instrument Off

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

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

To assign or reset the status flag bit assignments, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:



**Figure 6-10: COMM – Status Flag Bit Assignment**

**6.6.2.7. INSTRUMENT ID**

Each instrument on a Hessen Protocol network must have a unique identifier (ID number). Refer to Section 5.7.1 for information and to customize the ID of each.

## 7. DATA ACQUISITION SYSTEM (DAS) AND APICOM

The T100 analyzer contains a flexible and powerful, internal data acquisition system (DAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The DAS of the T100 can store several months of data, depending on individual configurations. The data are stored in non-volatile memory and are retained even when the instrument is powered off. Data are stored in plain text format for easy retrieval and use in common data analysis programs (such as spreadsheet-type programs).

The DAS is designed to be flexible, users have full control over the type, length and reporting time of the data. The DAS permits users to access stored data through the instrument's front panel or its communication ports. Using APICOM, data can even be retrieved automatically to a remote computer for further processing.

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

To support the DAS functionality, Teledyne API offers APICOM, a program that provides a visual interface for remote or local setup, configuration and data retrieval of the DAS. The APICOM manual, which is included with the program, contains a more detailed description of the DAS structure and configuration, which is briefly described in this section.

The T100 is configured with a basic DAS configuration, which is enabled by default. New data channels are also enabled by default but each channel may be turned off for later or occasional use. Note that DAS operation is suspended while its configuration is edited through the front panel. To prevent such data loss, it is recommended to use the APICOM graphical user interface for DAS changes.

The green SAMPLE LED on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the DAS status, as described in Table 7-1.

Table 7-1: Front Panel LED Status Indicators for DAS

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

**Note**

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

## 7.1. DAS STRUCTURE

The DAS is designed around the feature of a “record”. A record is a single data point of one parameter, stored in one (or more) data channels and generated by one of several triggering event. The entire DAS configuration is stored in a script, which can be edited from the front panel or downloaded, edited and uploaded to the instrument in form of a string of plain-text lines through the communication ports.

DAS data are defined by the PARAMETER type and are stored through different triggering EVENTS in data CHANNELS, which relate triggering events to data parameters and define certain operational functions related to the recording and reporting of the data.

### 7.1.1. DAS CHANNELS

The key to the flexibility of the DAS is its ability to store a large number of combinations of triggering events and data parameters in the form of data channels. Users may create up to 20 data channels and each channel can contain one or more parameters. For each channel one triggering event is selected and up to 50 data parameters, which can be the same or different between channels. Each data channel has several properties that define the structure of the channel and allow the user to make operational decisions regarding the channel (refer to Table 7-2).

Table 7-2: DAS Data Channel Properties

Property	Description	Default	Setting Range
<b>NAME</b>	The name of the data channel.	"NONE"	Up to 6 letters and digits (more with APICOM, but only the first six are displayed on the front panel).
<b>TRIGGERING EVENT</b>	The event that triggers the data channel to measure and store its data parameters. Refer to APPENDIX A for a list of available triggering events.	ATIMER	Any allowed event.
<b>NUMBER AND LIST OF PARAMETERS</b>	A User-configurable list of data types to be recorded in any given channel. Refer to APPENDIX A-5 for a list of available parameters	1 - PMTDET	Any available concentration, temperature, pneumatic or diagnostic parameter.
<b>REPORT PERIOD</b>	The amount of time between each channel data point.	000:01:00	000:00:01 to 366:23:59 (Days:Hours:Minutes)
<b>NUMBER OF RECORDS</b>	The number of reports that will be stored in the data file. Once the specified limit has been exceeded, the oldest data are over-written to make space for new data.	100	1 to 1 million, limited by available storage space.
<b>RS-232 REPORT</b>	Enables the analyzer to automatically report channel values to the RS-232 ports.	OFF	OFF or ON
<b>CHANNEL ENABLED</b>	Enables or disables the channel. Provides a convenient means to temporarily disable a data channel.	ON	OFF or ON
<b>CAL HOLD OFF</b>	Disables sampling of data parameters while the instrument is in calibration mode. Note that - when enabled here - there is also a length of the DAS HOLD OFF after calibration mode, which is set in the VARS menu (refer to Section 7.2.11).	OFF	OFF or ON

### 7.1.2. DAS PARAMETERS

Data parameters are types of data that may be measured and stored by the DAS. For each Teledyne API's analyzer model, the list of available data parameters is different, fully defined and not customizable. Appendix A lists firmware specific data parameters for the T100. The most common parameters are concentrations of the measured gas (SO<sub>2</sub>), temperatures of heated zones (converter, sample chamber, box temperature...), pressures and flows of the pneumatic subsystem and other diagnostic measurements as well as calibration data (slope and offset) for each gas.

Most data parameters have associated measurement units, such as mV, ppb, cm<sup>3</sup>/min, etc., although some parameters have no units. The only units that can be changed are those of the concentration readings according to the **SETUP-RANGE** settings. Note that the DAS does not keep track of the unit of each concentration value and DAS data files may contain concentrations in multiple units if the unit was changed during data acquisition.

Each data parameter has user-configurable functions that define how the data are recorded (refer to Table 7-3).

Table 7-3: DAS Data Parameter Functions

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

Users can specify up to 50 parameters per data channel (the T100 provides about 30 parameters). However, the number of parameters and channels is ultimately limited by available memory.

### 7.1.3. DAS TRIGGERING EVENTS

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

- **ATIMER**: Sampling at regular intervals specified by an automatic timer. Most trending information is usually stored at such regular intervals, which can be instantaneous or averaged.
- **EXITZR, EXITSP, SLPCHG** (exit zero, exit span, slope change): Sampling at the end of (irregularly occurring) calibrations or when the response slope changes. These triggering events create instantaneous data points, e.g., for the new slope and offset (concentration response) values at the end of a calibration. Zero and slope values are valuable to monitor response drift and to document when the instrument was calibrated.
- **WARNINGS**: Some data may be useful when stored if one of several warning messages appears. This is helpful for trouble-shooting by monitoring when a particular warning occurred.

## 7.2. DEFAULT DAS CHANNELS

A set of default Data Channels has been included in the analyzer's software for logging SO<sub>2</sub> concentration and certain predictive diagnostic data. These default channels include but are not limited to:

**CONC**: Samples SO<sub>2</sub> concentration at one minute intervals and stores an average every five minutes with a time and date stamp. Readings during calibration and calibration hold off are not included in the data. By default, the last 4032 hourly averages are stored.

**PNUMTC:** Collects sample flow and sample pressure data at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring the condition of the pump and critical flow orifice (sample flow) and the sample filter (clogging indicated by a drop in sample pressure) over time to predict when maintenance will be required. The last 360 daily averages (about 1 year) are stored.

**CALDAT:** Logs new slope and offset every time a zero or span calibration is performed. This Data Channel also records the instrument reading just prior to performing a calibration. *Note:* this Data Channel collects data based on an event (a calibration) rather than a timer. This Data Channel will store data from the last 200 calibrations. This does not represent any specific length of time since it is dependent on how often calibrations are performed. As with all Data Channels, a time and date stamp is recorded for every data point logged.

**DETAIL:** Samples fourteen different parameters related to the operating status of the analyzers optical sensors and PMT. For each parameter:

- A value is logged once every minute;
- An average of the last 60 readings is calculated once every.
- The last 480 averages are stored (20 days).

This channel is useful for diagnosing problems that cause the instruments measurements to drift slowly over time

**FAST:** Almost identical to **DETAIL** except that for each parameter:

- Samples are taken once per minute and reported once per minute, in effect causing the instrument to record an instantaneous reading of each parameter every minute.
- The last 360 readings for each parameter are recorded/reported.

This channel is useful for diagnosing transients; spikes and noise problems.

These default Data Channels can be used as they are, or they can be customized to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels. This can be done via the instrument's front panel or downloaded via the analyzer's COM ports using a program such as APICOM (Section 7.3) or other terminal emulation program.

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**IMPORTANT**

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**IMPACT ON READINGS OR DATA**

**Sending a DAS configuration to the analyzer through its COM ports will replace the existing configuration and will delete all stored data. Back up any existing data and the DAS configuration before uploading new settings**

---

The Channel Properties, Triggering Events and Data Parameters/Functions for these default channels are:

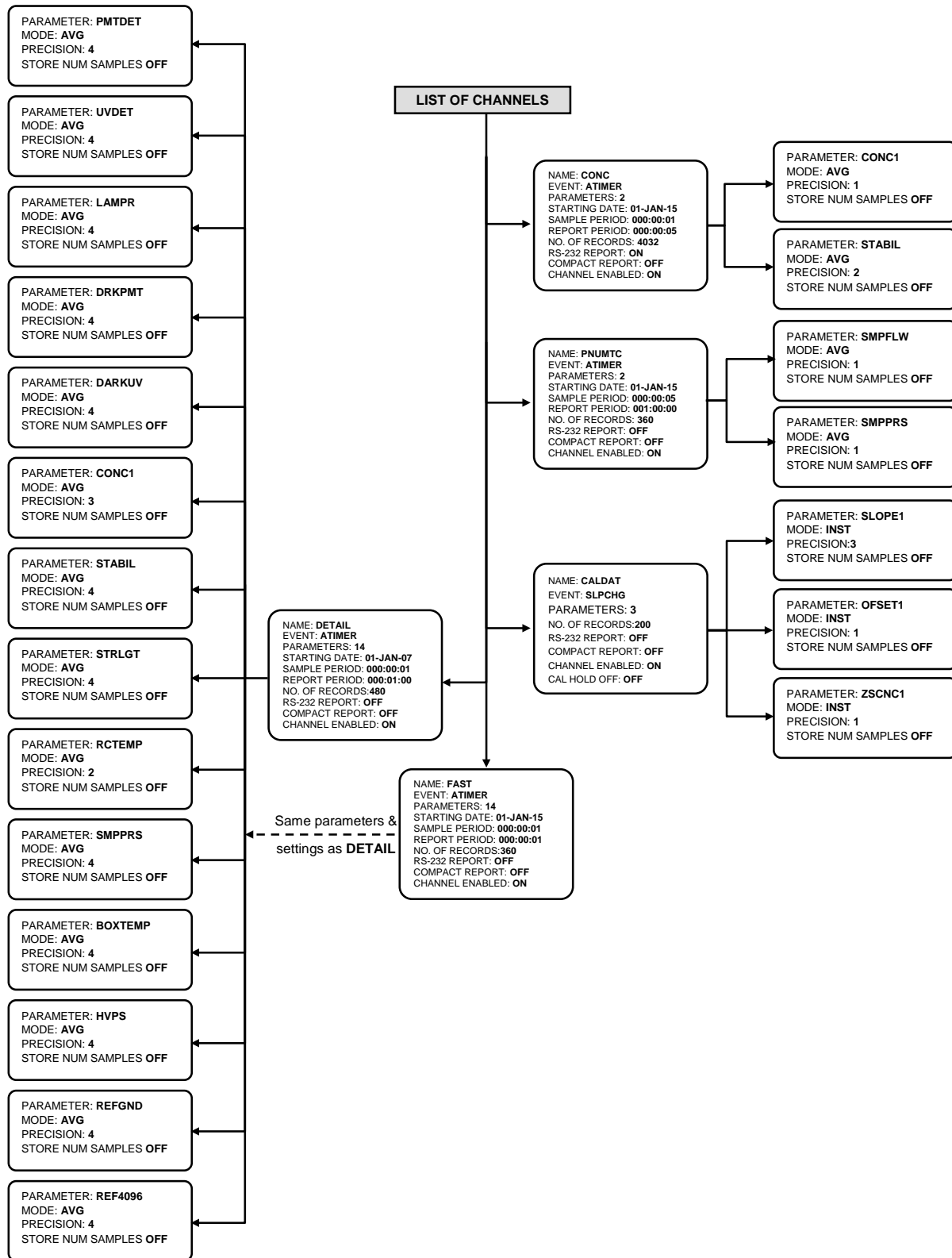


Figure 7-1: Default DAS Channels Setup



### 7.2.1. VIEWING DAS DATA AND SETTINGS

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

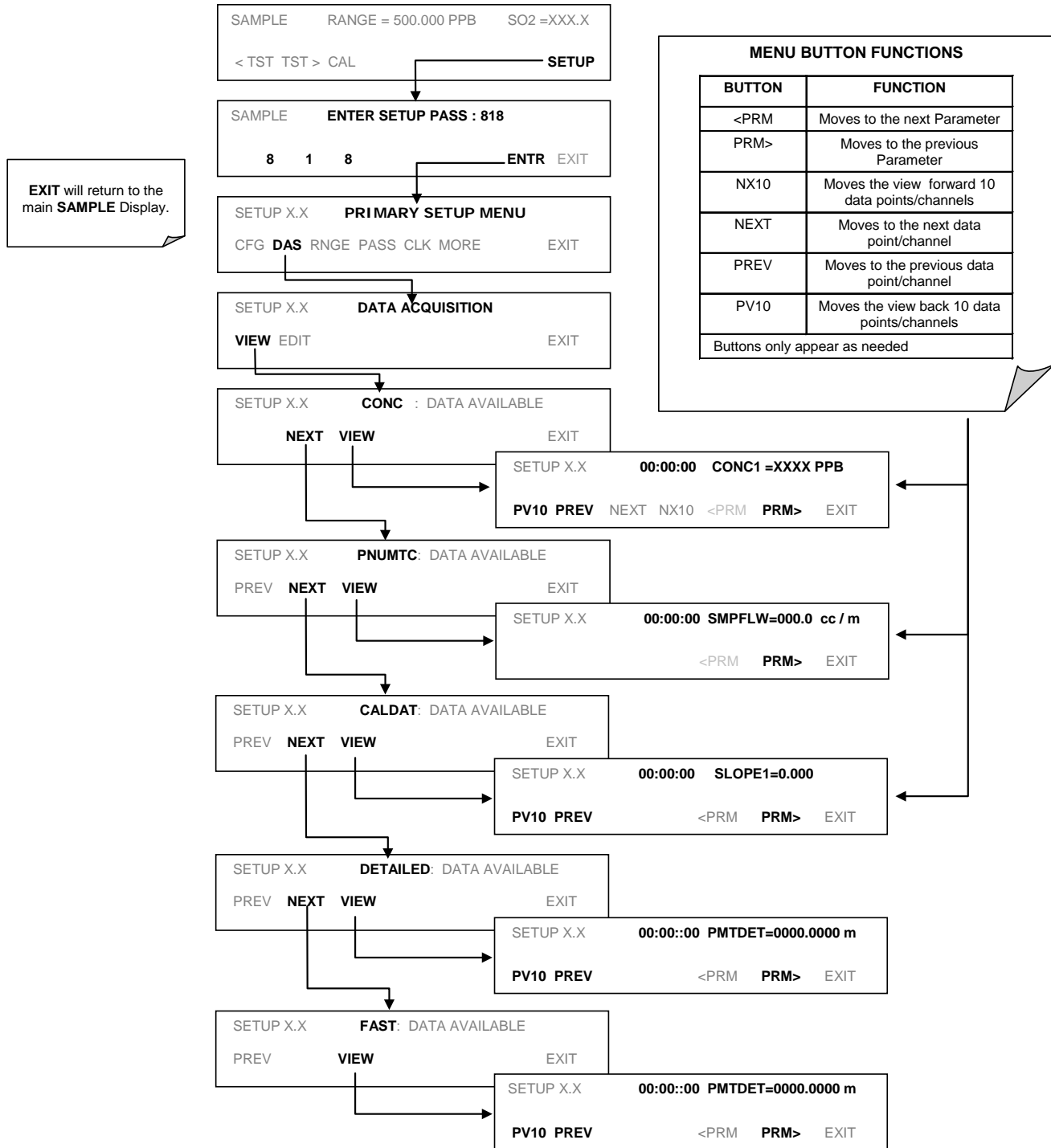


Figure 7-2: DAS – Data Acquisition Menu

### 7.2.2. 7.3 EDITING DAS DATA CHANNELS

Although DAS configuration is most conveniently done through the APICOM remote control program (refer to Section ), the following illustrations shows how to edit DAS channels using the analyzer's front panel control buttons.

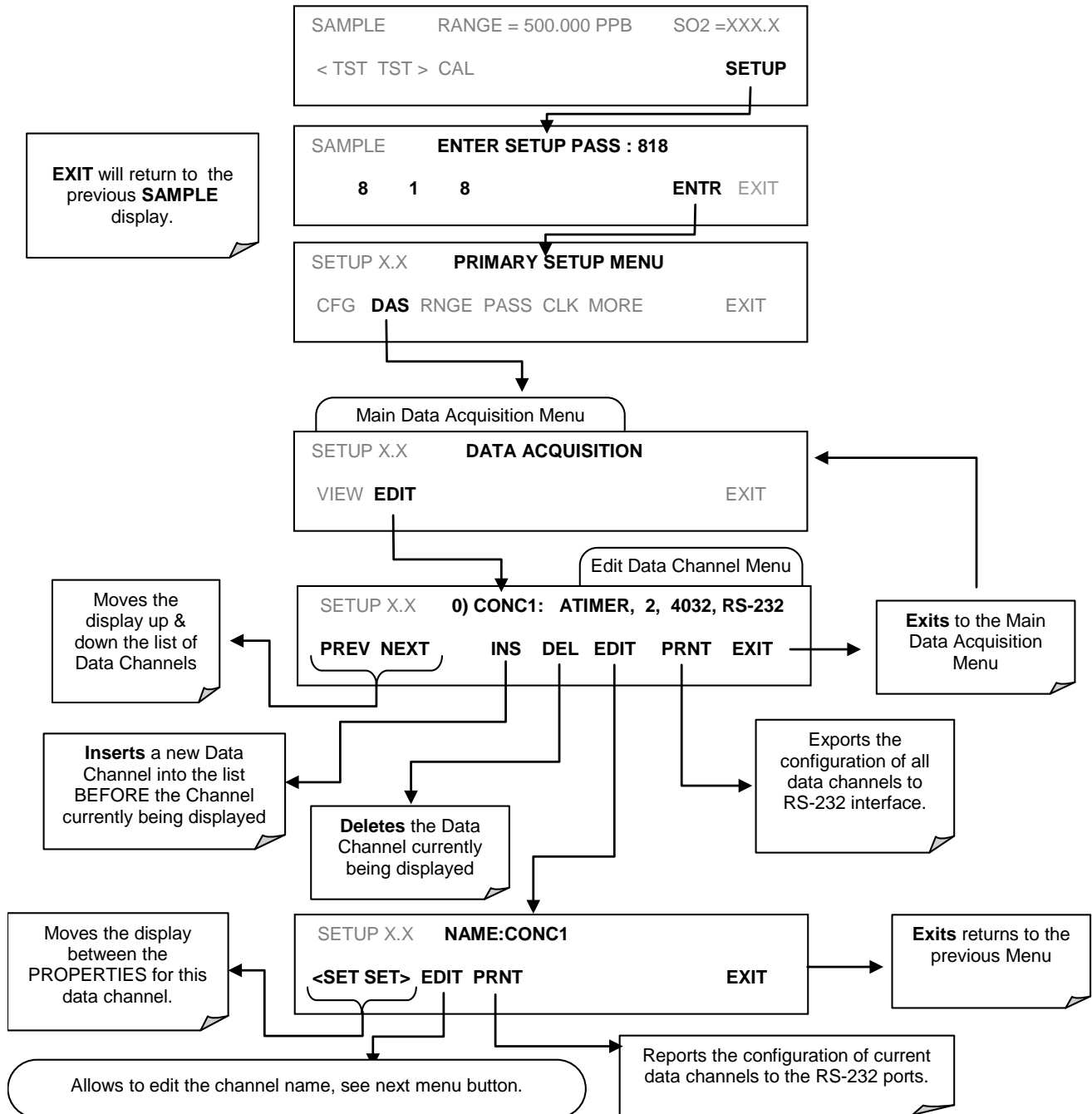


Figure 7-3: DAS – Editing DAS Data Channels

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

**0) CONC: ATIMER, 4, 800**

represents to the following configuration:

CHANNEL NUMBER.: **0**

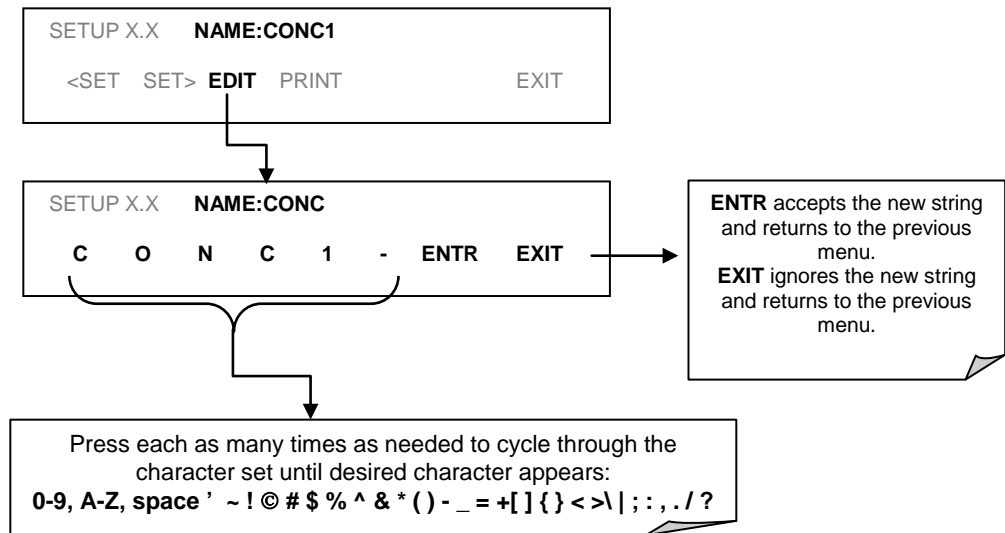
NAME: **CONC**

TRIGGER EVENT: **ATIMER**

PARAMETERS: **Four** parameters are included in this channel

EVENT: This channel is set up to record **800** data points.

To edit the name of a data channel, refer to Figure 7-3, then press:



**Figure 7-4: DAS – Editing Data Channel Name**

### 7.2.3. TRIGGER EVENTS

To edit the list of data parameters associated with a specific data channel, refer to the DATA Acquisition Menu (refer to Figure 7-2), then press:

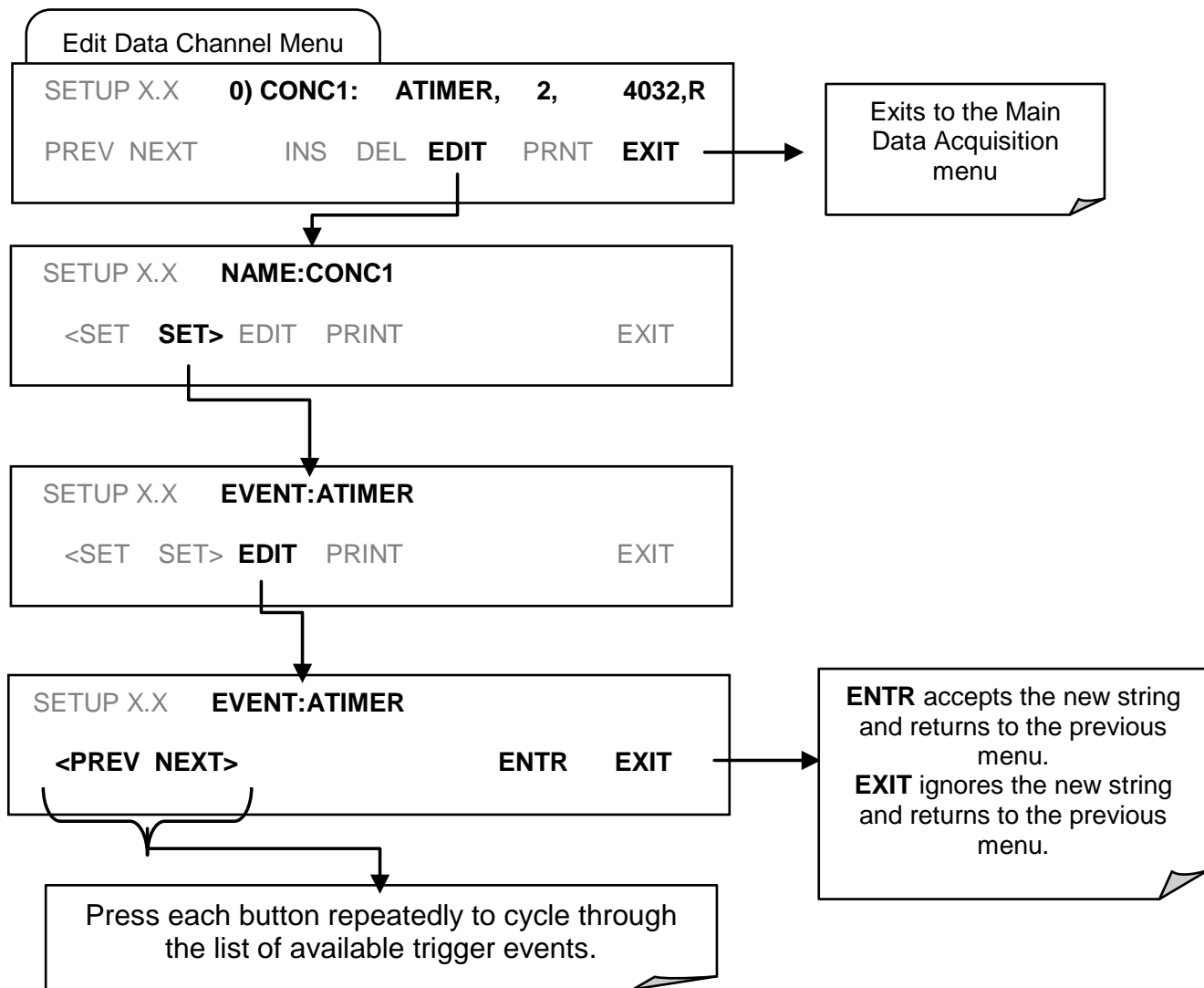


Figure 7-5: DAS – Trigger Events

### 7.2.4. EDITING DAS PARAMETERS

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

To modify, add or delete a parameter, follow the instruction shown in Figure 7-3, then press:

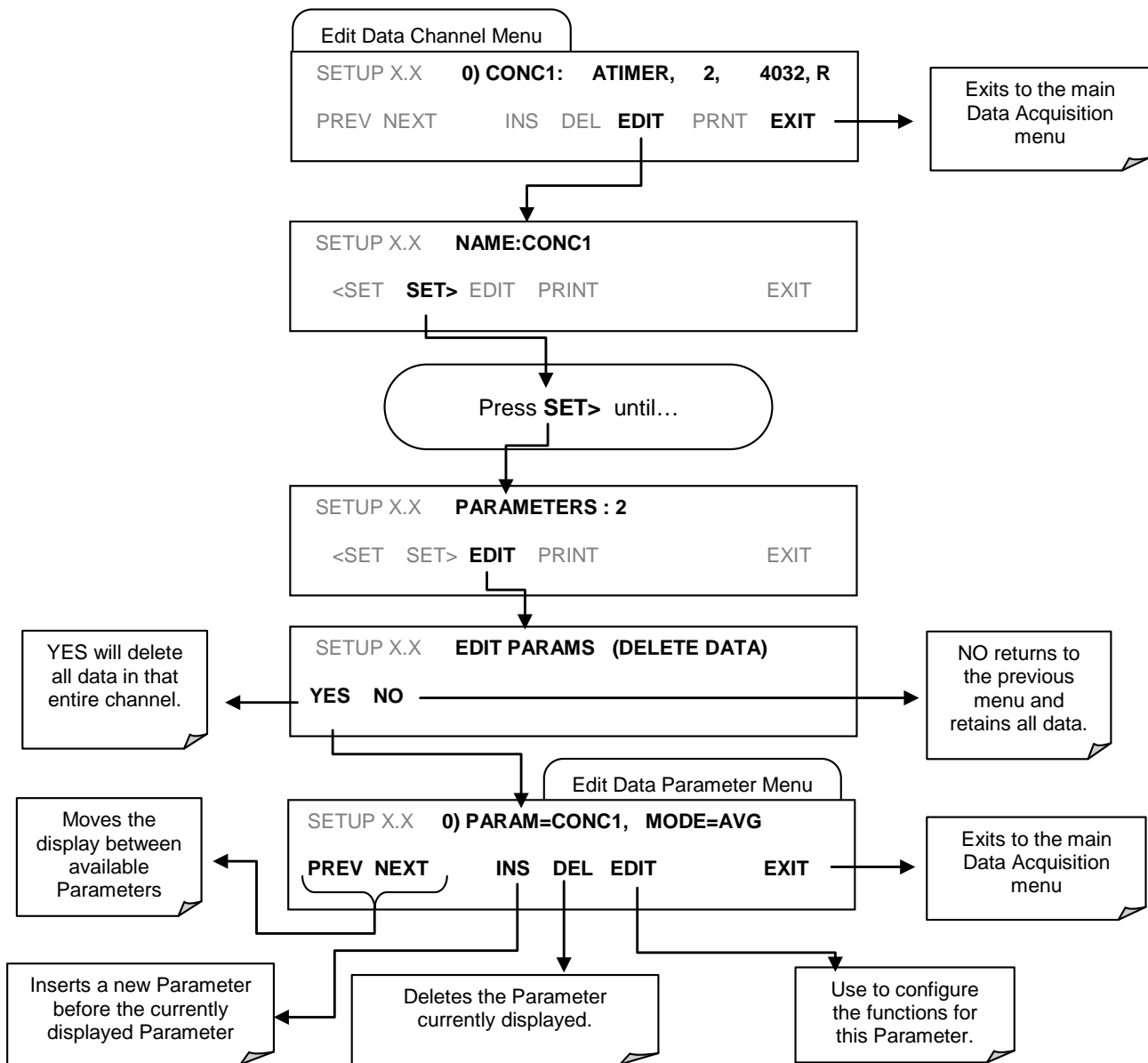


Figure 7-6: DAS – Editing DAS Parameters

To configure the parameters for a specific data parameter, follow the instructions as shown in Figure 7-6, then press:

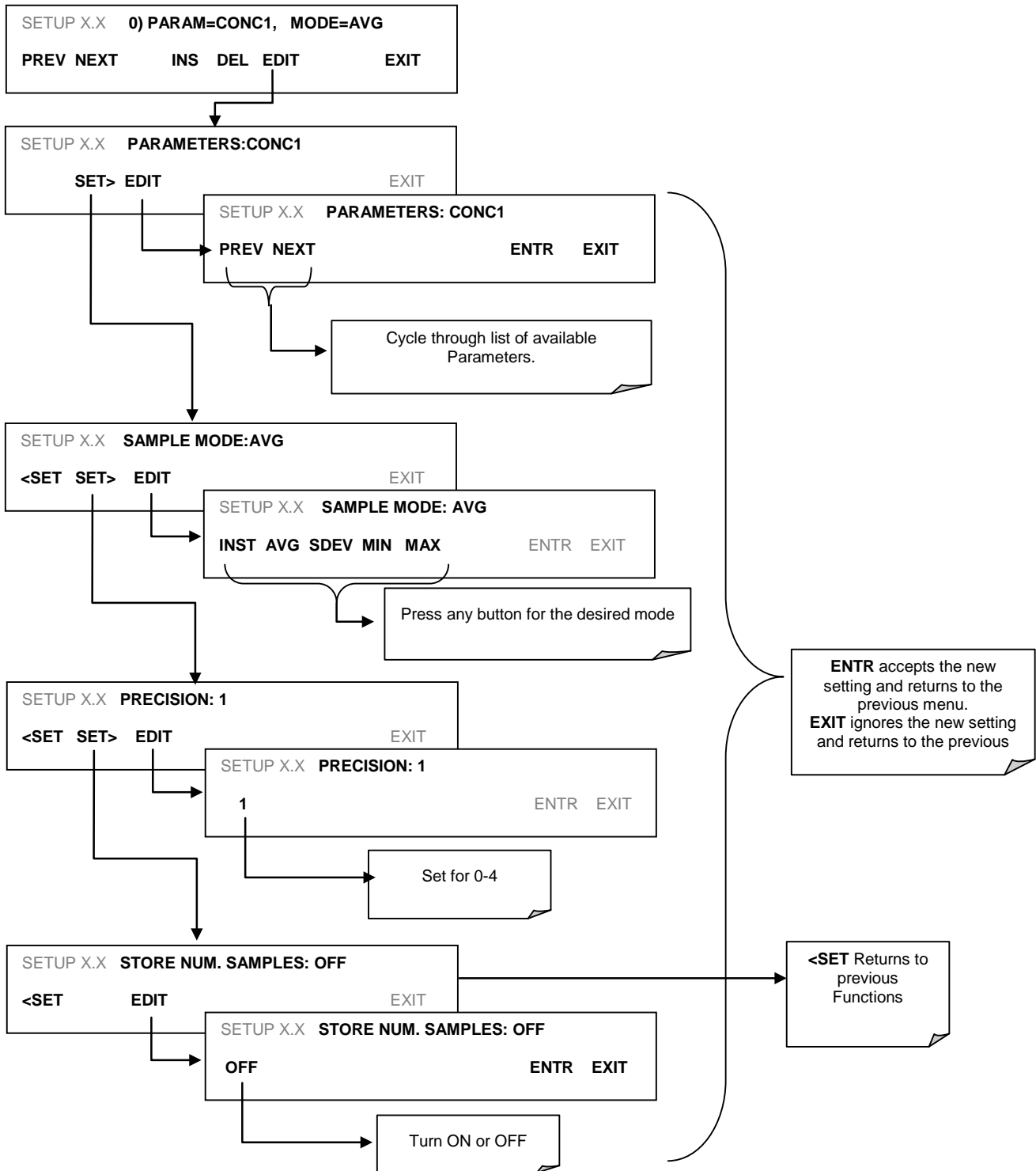


Figure 7-7: DAS – Configuring Parameters for a Specific Data Parameter

## 7.2.5. SAMPLE PERIOD AND REPORT PERIOD

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

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

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

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

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

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

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

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

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

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

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

### **REPORT PERIODS IN PROGRESS WHEN INSTRUMENT IS POWERED OFF**

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

To define the **REPORT PERIOD**, follow the instruction shown in Figure 7-3, then press:

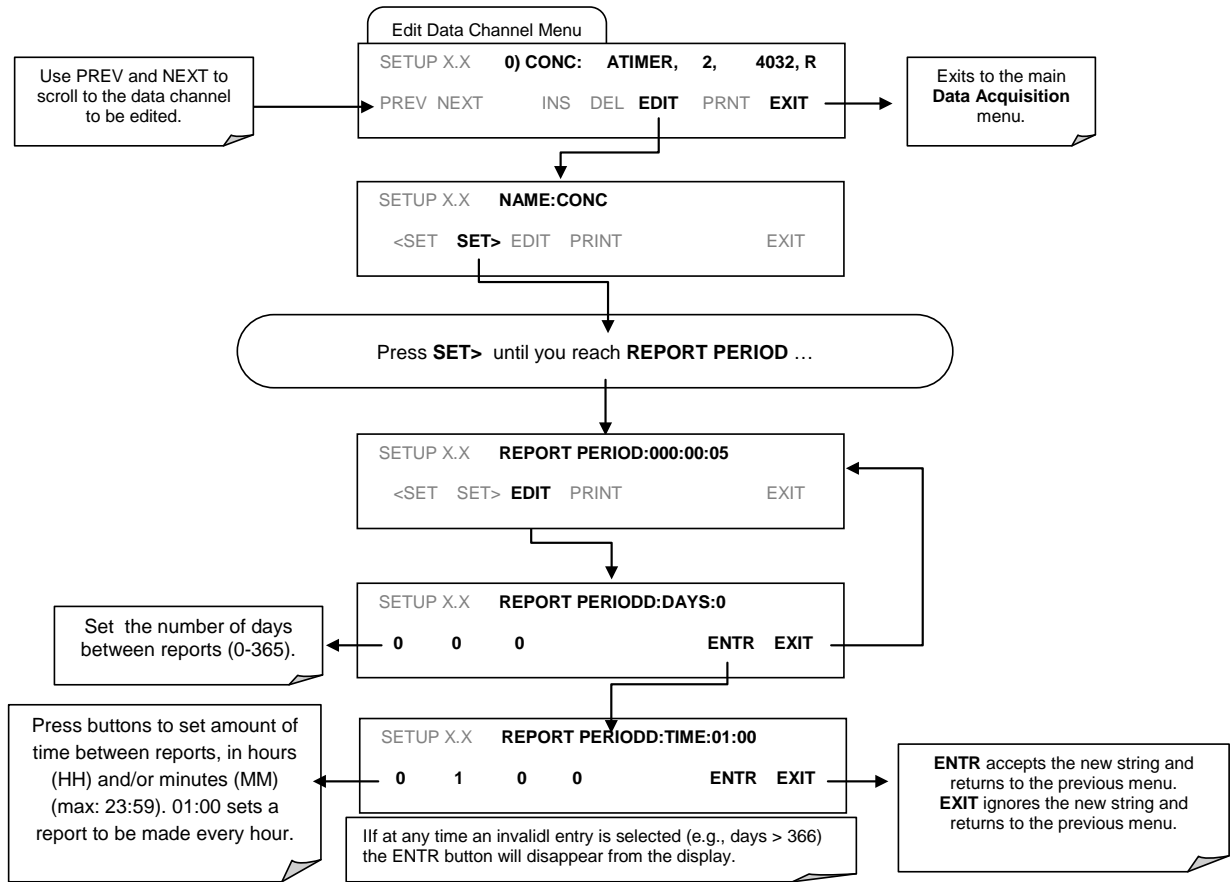


Figure 7-8: DAS – Define the Report Period

### 7.2.6. NUMBER OF RECORDS

Although the DAS is capable of capturing several months worth of data, the actual number of records is also limited by the total number of parameters and channels and other settings in the DAS configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points somewhat. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

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



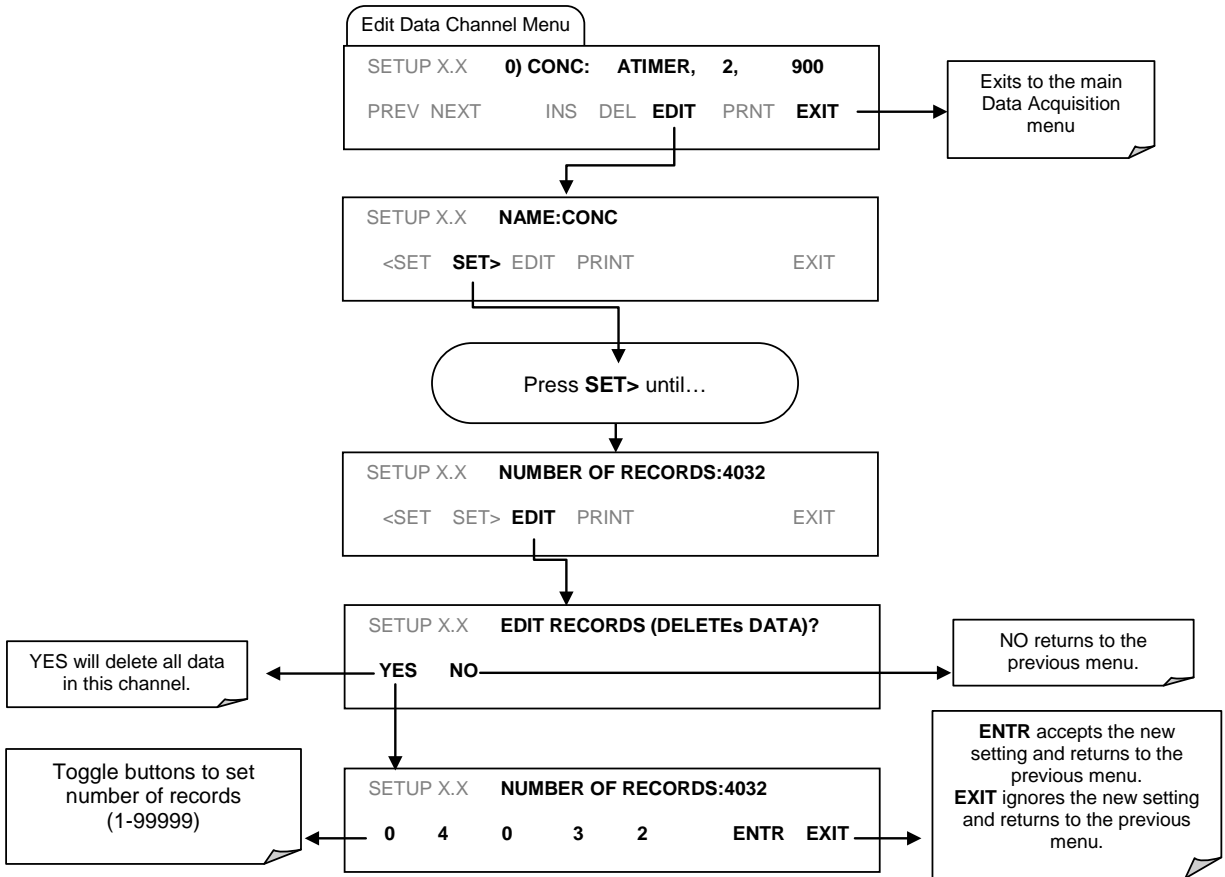


Figure 7-9: DAS – Edit Number of Records

### 7.2.7. RS-232 REPORT FUNCTION

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

To enable automatic COMM port reporting, follow the instruction shown in Figure 7-3, then press:

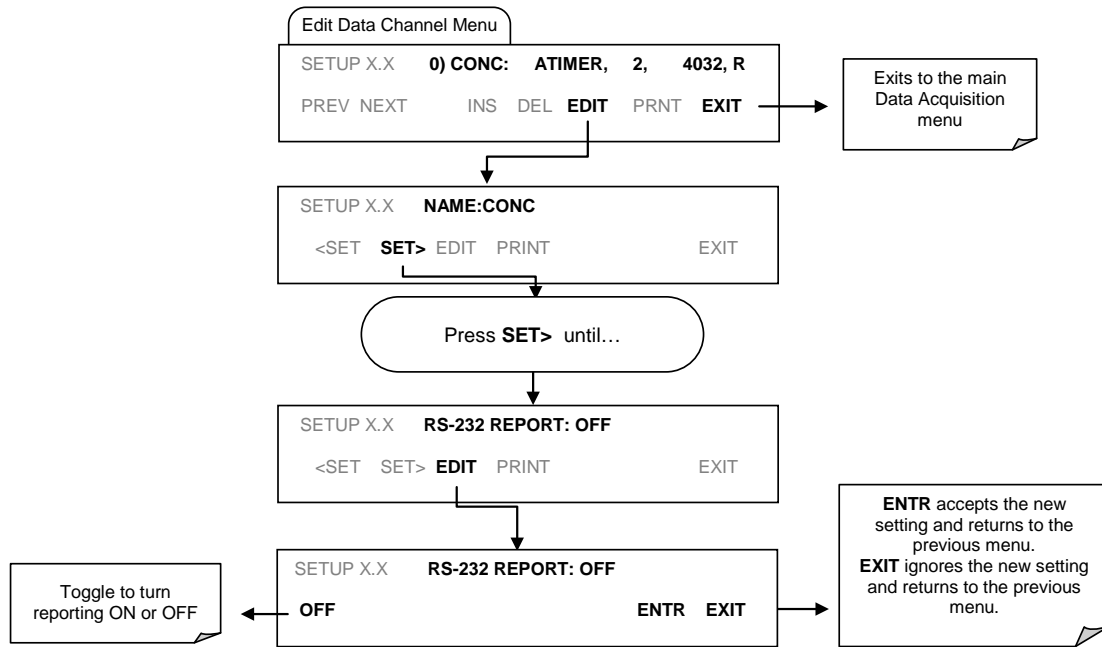


Figure 7-10: DAS – RS-232 Report Function

### 7.2.8. COMPACT REPORT

When enabled, this option avoids unnecessary line breaks on all RS-232 reports. Instead of reporting each parameter in one channel on a separate line, up to five parameters are reported in one line, instead.

### 7.2.9. STARTING DATE

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

### 7.2.10. DISABLING/ENABLING DATA CHANNELS

Data channels can be temporarily disabled, which can reduce the read/write wear on the disk-on-module. The ALL\_01 channel of the T100, for example, is disabled by default.

To disable a data channel, follow the instruction shown in Figure 7-3, then press:

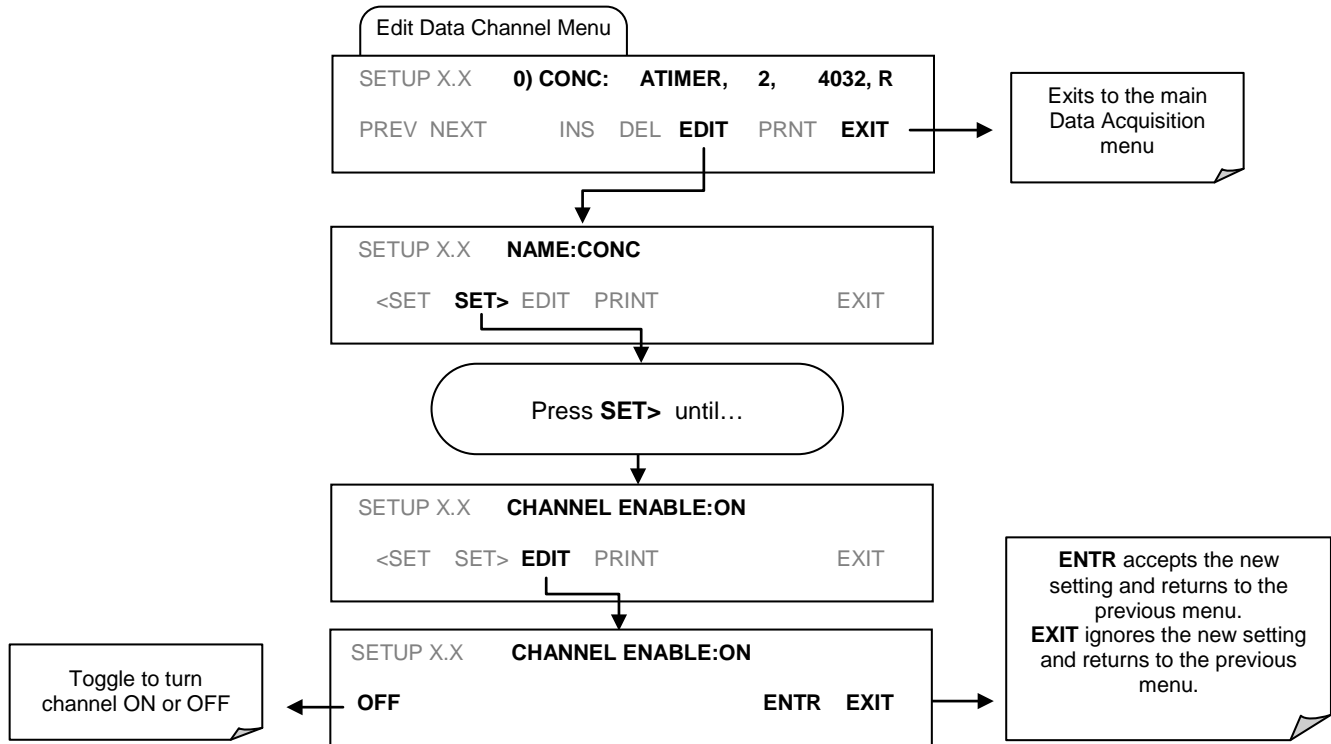


Figure 7-11: DAS – Disabling / Enabling Data Channels

### 7.2.11. HOLDOFF FEATURE

The DAS HOLDOFF feature prevents data collection during calibrations and during the DAS\_HOLDOFF period enabled and specified in the VARS (refer to Section 5.8).

To enable or disable the HOLDOFF, follow the instruction shown in Figure 7-3, then press:

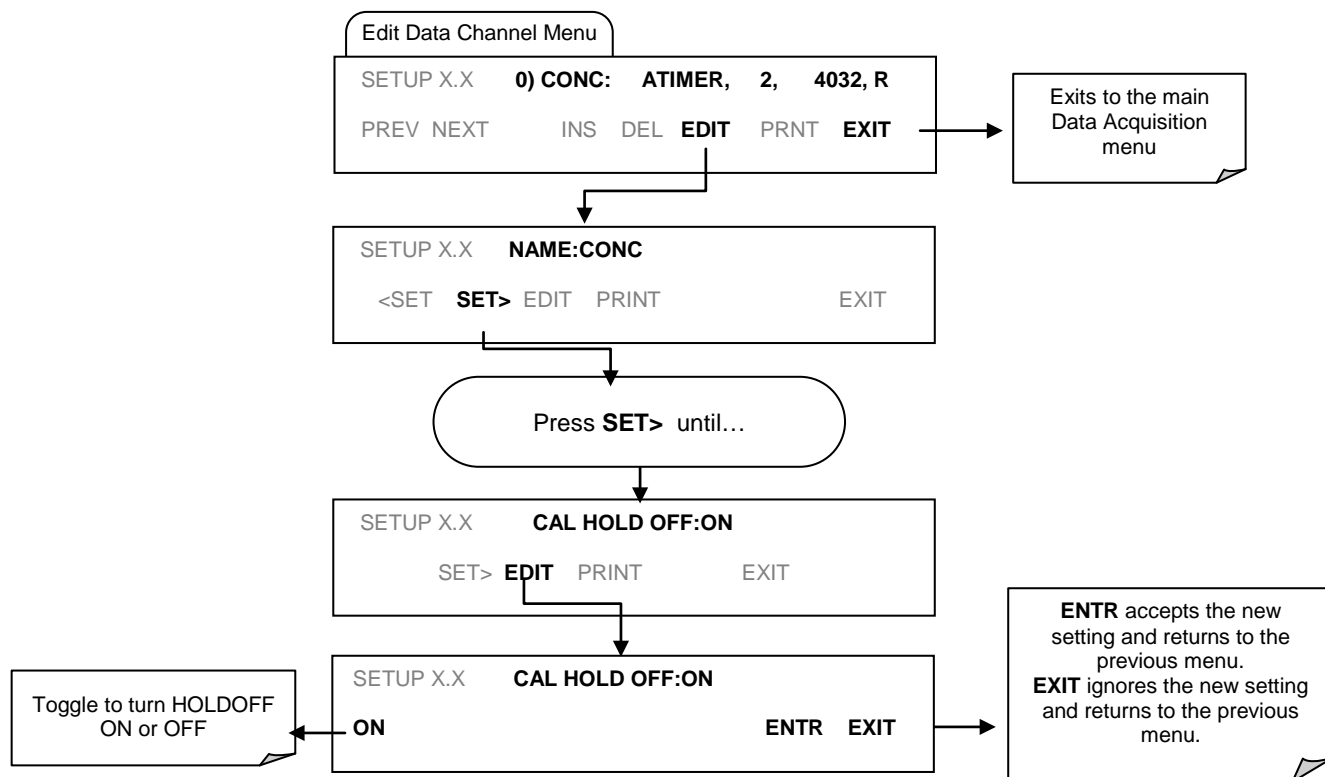


Figure 7-12: DAS – Holdoff Feature

The DAS can be configured and operated remotely via the APICOM program.

## 7.3. APICOM REMOTE CONTROL PROGRAM

APICOM is an easy-to-use, yet powerful interface program that allows a 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 T100 through direct cable connection via RS-232 modem or Ethernet.
- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.
- Remotely edit system parameters and set points.
- Download, view, graph and save data for predictive diagnostics or data analysis.
- Retrieve, view, edit, save and upload DAS configurations (Section 7.4).
- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and troubleshooting. Figure 7-15 shows an example of APICOM being used to remotely configuration the DAS feature. Figure 7-13 shows examples of APICOM's main interface, which emulates the look and functionality of the instrument's actual front panel:

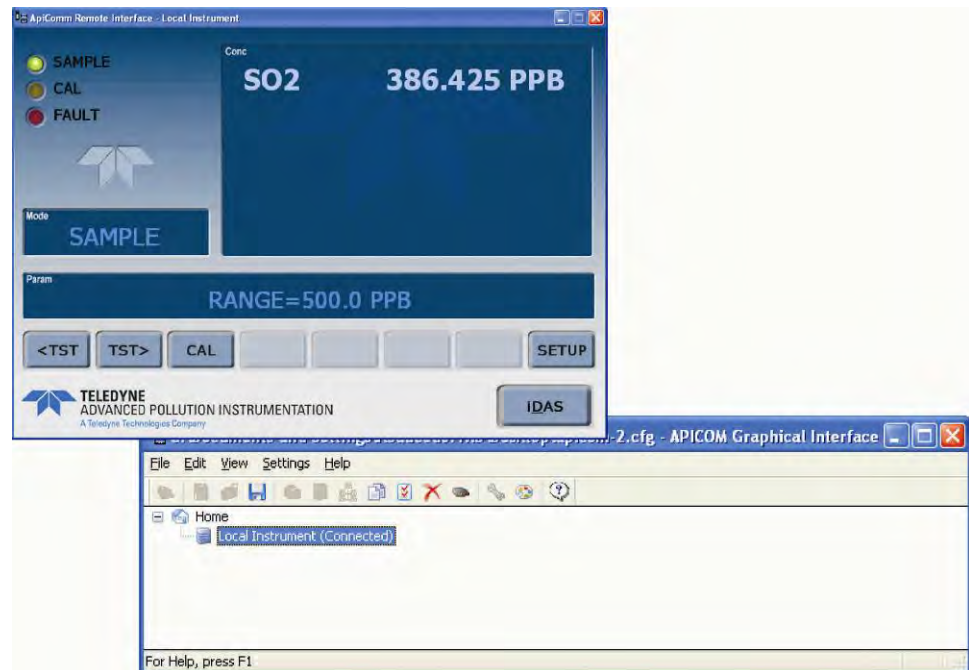
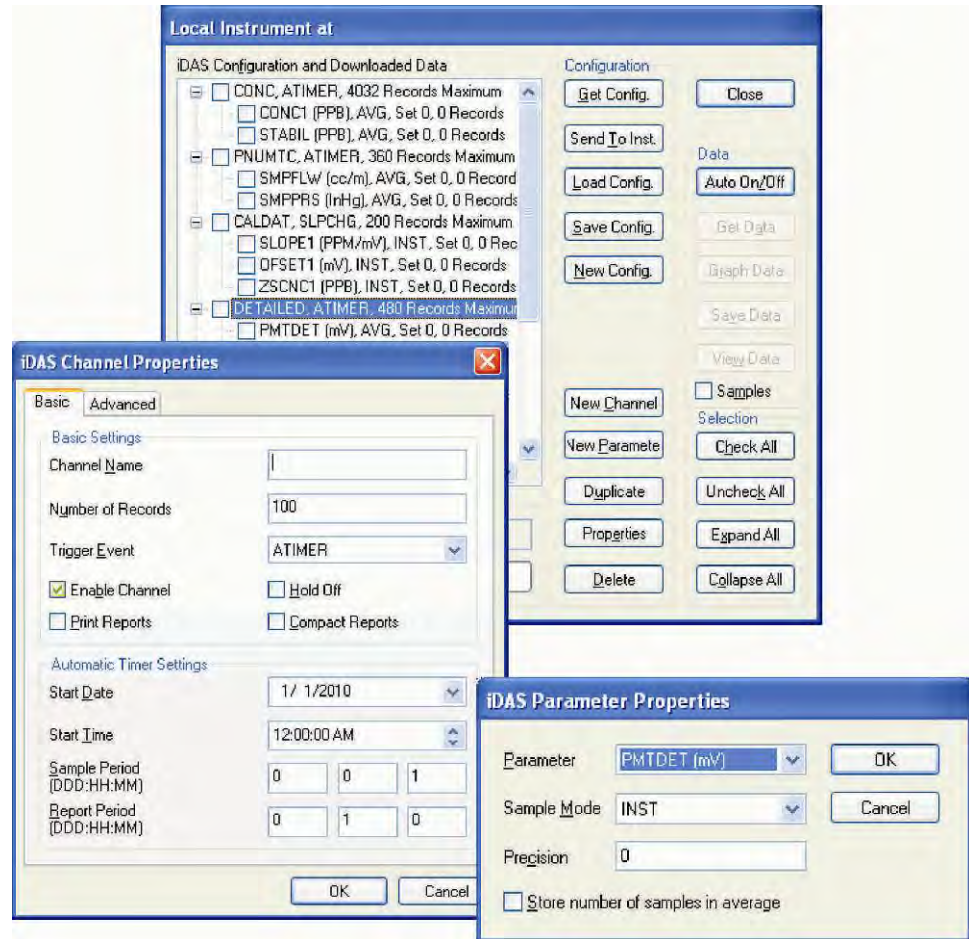


Figure 7-13: APICOM Remote Control Program Interface

APICOM is included with the analyzer and the latest versions can also be downloaded at no charge at <http://www.teledyne-api.com/software/apicom/>.

## 7.4. REMOTE DAS CONFIGURATION VIA APICOM

Editing channels, parameters and triggering events as described in this section is performed via the APICOM remote control program using the graphic interface similar to the example shown in Figure 7-14. Refer to Section 8 for details on remote access to the T100 analyzer.



**Figure 7-14: Sample APICOM User Interface for Configuring the DAS**

Once a DAS configuration is edited (which can be done offline and without interrupting DAS data collection), it is conveniently uploaded to the instrument and can be stored on a computer for later review, alteration or documentation and archival. Refer to the APICOM manual for details on these procedures. The APICOM user manual (Teledyne API's P/N 039450000) is included in the APICOM installation file, which can be downloaded at <http://www.teledyne-api.com/software/apicom/>.

Although Teledyne API recommends the use of APICOM, the DAS can also be accessed and configured through a terminal emulation program such as HyperTerminal (refer to Figure 7-15). However, all configuration commands must be created following a strict syntax or be pasted in from of a text file, which was edited offline and then uploaded through a specific transfer procedure.

```
Instrument HyperTerminal
File Edit View Call Transfer Help
SETUP PROPERTIES FOR ENGDAT:
NAME: ENGDAT
EVENT: ATIMER
REPORT PERIOD: 000:00:02
NUMBER OF RECORDS: 2000
RS-232 REPORT: ON
CHANNEL ENABLED: ON
CAL. HOLD OFF: OFF
PARAMETERS: 14
PARAMETER=RCTEMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=CNVTMP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=PMITTWP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=BOXTWP, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=O3FLOW, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=SMPFLW, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=SMPPRS, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=RCPRES, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=AZERO, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=HVPS, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=PMTDET, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=RF4096, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
PARAMETER=REFGND, MODE=AVG, PRECISION=4, STORE_SAMPLES=OFF
Connected 06:01:32 | Auto detect | TCP/IP | SCROLL | COPY | NUM | Capture | Print
```

Figure 7-15: DAS Configuration Through a Terminal Emulation Program

Both procedures are best started by downloading the default DAS configuration, getting familiar with its command structure and syntax conventions, and then altering a copy of the original file offline before uploading the new configuration.

## IMPORTANT

### IMPACT ON READINGS OR DATA

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

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## 8. REMOTE OPERATION OF THE ANALYZER

This section provides information needed when using external digital and serial I/O and when using Hessen protocol for remote operation. It also provides references to communications-related manuals.

### 8.1. REMOTE OPERATION USING THE EXTERNAL DIGITAL I/O

#### 8.1.1. STATUS OUTPUTS

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

#### ATTENTION

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

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

-----

The status outputs are accessed through a 12 pin connector on the analyzer's rear panel labeled STATUS (refer to Figure 3-4). The function of each pin is defined in Table 8-1.

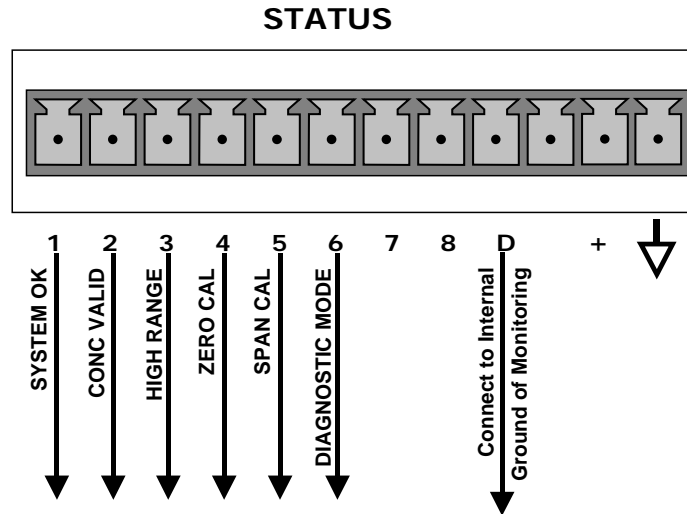


Figure 8-1: Status Output Connector

Table 8-1: Status Output Pin Assignments

CONNECTOR PIN	STATUS	CONDITION (ON=CONDUCTING)
1	System Ok	ON if no faults are present.
2	Conc Valid	ON if concentration measurement is valid, OFF when invalid.
3	High Range	ON if unit is in high range of any AUTO range mode.
4	Zero Cal	ON whenever the instrument is in ZERO calibration mode.
5	Span Cal	ON whenever the instrument is in SPAN calibration mode.
6	Diag Mode	ON whenever the instrument is in DIAGNOSTIC mode.
7-8		Unused
D	Emitter Bus	The emitters of the transistors on pins 1-8 are bussed together. For most applications, this pin should be connected to the circuit ground of the receiving device.
+	Dc Power	+ 5 VDC source, 30 mA maximum (combined rating with Control Inputs)
⚡	Digital Ground	The ground from the analyzer's internal, 5/±15 VDC power supply.

### 8.1.2. CONTROL INPUTS

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

Table 8-2: Control Input Pin Assignments

INPUT	STATUS	CONDITION WHEN ENABLED
A	External Zero Cal	Zero calibration mode is activated. The mode field of the display will read ZERO CAL R.
B	External Span Cal	Span calibration mode is activated. The mode field of the display will read SPAN CAL R.
C		Unused
D		Unused
E		Unused
F		Unused
⏚	Digital Ground	Provided to ground an external device (e.g., recorder).
U	DC Power For Input Pull Ups	Input for +5 VDC required to activate inputs A - F. This voltage can be taken from an external source or from the "+" pin.
+	Internal +5v Supply	Internal source of +5V which can be used to activate inputs when connected to pin U.

There are two methods to activate control inputs. The internal +5V available from the "+" pin is the most convenient method (Figure 8-2). However, to ensure that these inputs are truly isolated, a separate, external 5 VDC power supply should be used (Figure 8-3).

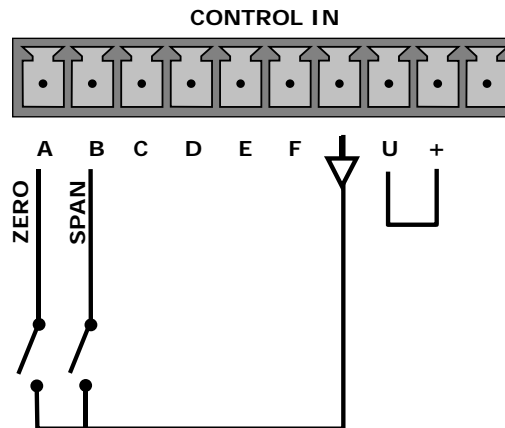


Figure 8-2: Control Inputs with Local 5 V Power Supply

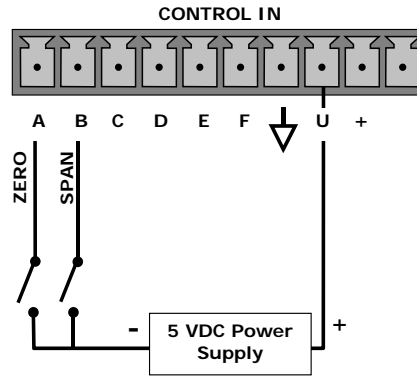


Figure 8-3: Control Inputs with External 5 V Power Supply

## 8.2. REMOTE OPERATION USING THE EXTERNAL SERIAL I/O

### 8.2.1. TERMINAL OPERATING MODES

The T100 can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the analyzer supports two communication modes specifically designed to interface with these two types of devices.

**Computer mode** is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM. More information regarding APICOM can be found in later in this section or on the Teledyne API's website at <http://www.teledyne-api.com/software/apicom/>.

**Interactive mode** is used with a terminal emulation programs such as HyperTerminal or a "dumb" computer terminal. The commands that are used to operate the analyzer in this mode are listed in Table 8-3 and in Appendix A-6.

### 8.2.2. HELP COMMANDS IN TERMINAL MODE

Table 8-3: Terminal Mode Software Commands

Command	Function
Control-T	Switches the analyzer to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
Control-C	Switches the analyzer to computer mode (no echo, no edit).
CR (carriage return)	A carriage return is required after each command line is typed into the terminal/computer. The command will not be sent to the analyzer to be executed until this is done. On personal computers, this is achieved by pressing the ENTER 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 analyzer is only necessary if multiple analyzers are on the same communications line, such as the multi-drop setup.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

### 8.2.3. COMMAND SYNTAX

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

All Commands follow the syntax:

**X [ID] COMMAND <CR>**

Where:

**X** is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 6-25 and Appendix A-6.

**[ID]** is the analyzer identification number (refer to Section 5.7.1). Example: the Command "? 200" followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 200.

**COMMAND** is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press? <CR> or refer to Appendix A-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 8-4: Command Types**

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

### 8.2.4. DATA TYPES

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

**Integer** data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, *+1, -12, 123* are all valid integers.

**Hexadecimal** integer data are used for the same purposes as integers. They consist of the two characters "0x," followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the 'C' programming language convention. No plus or minus sign is permitted. For example, *0x1, 0x12, 0x1234abcd* are all valid hexadecimal integers.

**Floating-point numbers** are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point, and zero or more digits. (At least one digit must appear before or after the decimal point.) Scientific notation is not permitted. For example, *+1.0, 1234.5678, -0.1, 1* are all valid floating-point numbers.

**Boolean expressions** are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the keywords *ON* and *OFF*.

**Text strings** are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark, followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, “a”, “1”, “123abc”, and “( ) [ ] < >” are all valid text strings. It is not possible to include a quotation mark character within a text string.

Some commands allow you to access variables, messages, and other items, such as DAS data channels, by name. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

## 8.2.5. STATUS REPORTING

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (refer to Section 6.2.1 and Table 6-1).

Status reports include DAS data (when reporting is enabled), warning messages, calibration, and diagnostic status messages. Refer to Appendix A for a list of the possible messages, and this section for information on controlling the instrument through the RS-232 interface.

### 8.2.5.1. GENERAL MESSAGE FORMAT

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

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

Where:

**X** is a command type designator, a single character indicating the message type, as shown in the Table 6-25.

**DDD:HH:MM** is the time stamp, the date and time when the message was issued. It consists of the Day-of-year (DDD) as a number from 1 to 366, the hour of the day (HH) as a number from 00 to 23, and the minute (MM) as a number from 00 to 59.

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

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

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

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

### 8.3. REMOTE ACCESS BY MODEM

The T100 can be connected to a modem for remote access. This requires a cable between the analyzer's COM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

Once the cable has been connected, check to ensure that the DTE-DCE is in the correct position (refer to Section 6.1). Also ensure that the T100 COM port is set for a baud rate that is compatible with the modem, which needs to operate with an 8-bit word length with one stop bit.

The first step is to turn on the **MODEM ENABLE** communication mode (Mode 64, Section 6.2.1). Once this is completed, the appropriate setup command line for your modem can be entered into the analyzer. The default setting for this feature is:

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

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

To change this setting, access the COMMUNICATIONS Menu (SETUP>MORE.COMM), then press:

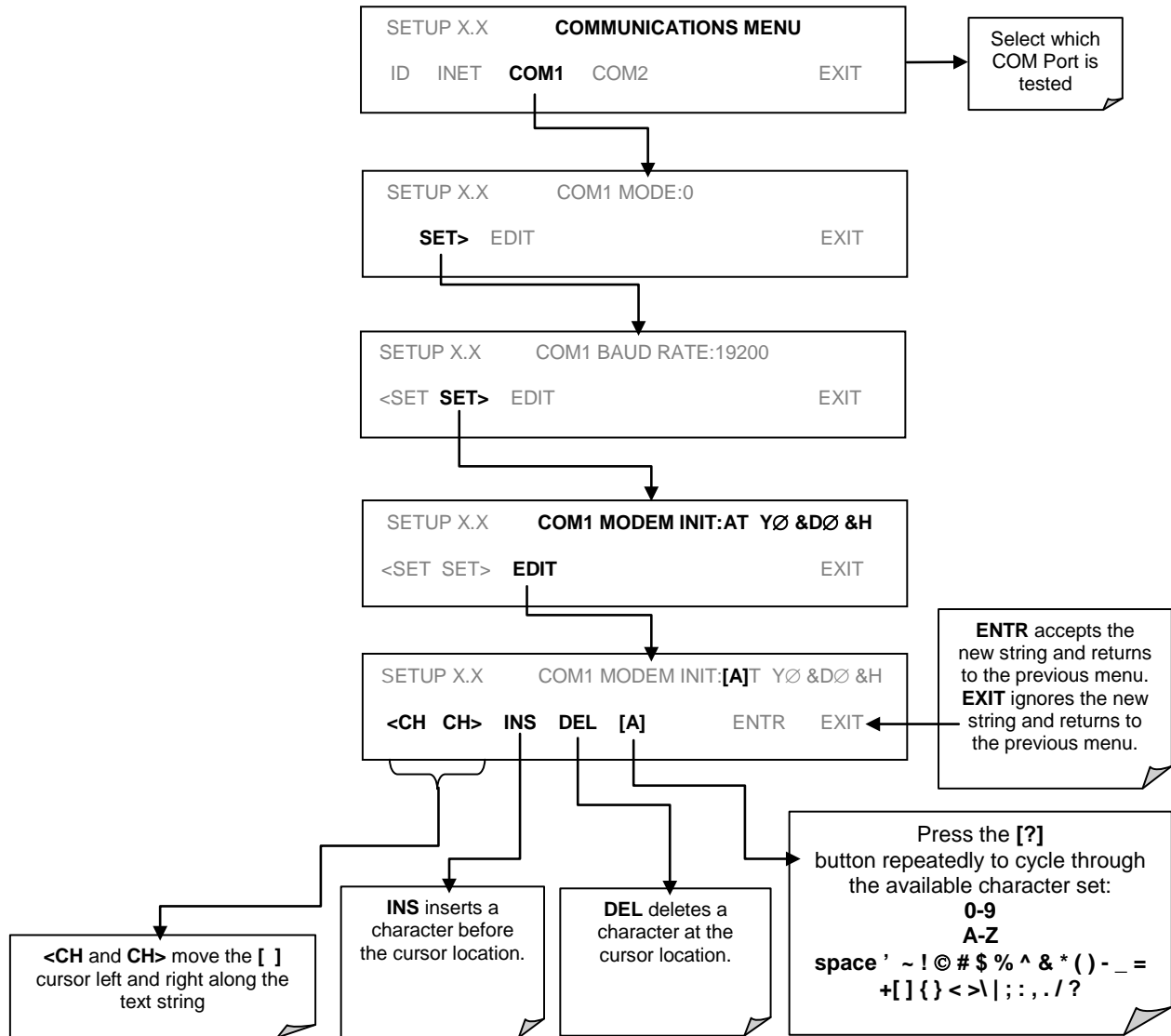


Figure 8-4: COMM – Remote Access by Modem



To initialize the modem, access the COMMUNICATIONS Menu (SETUP>MORE>COMM), then press:

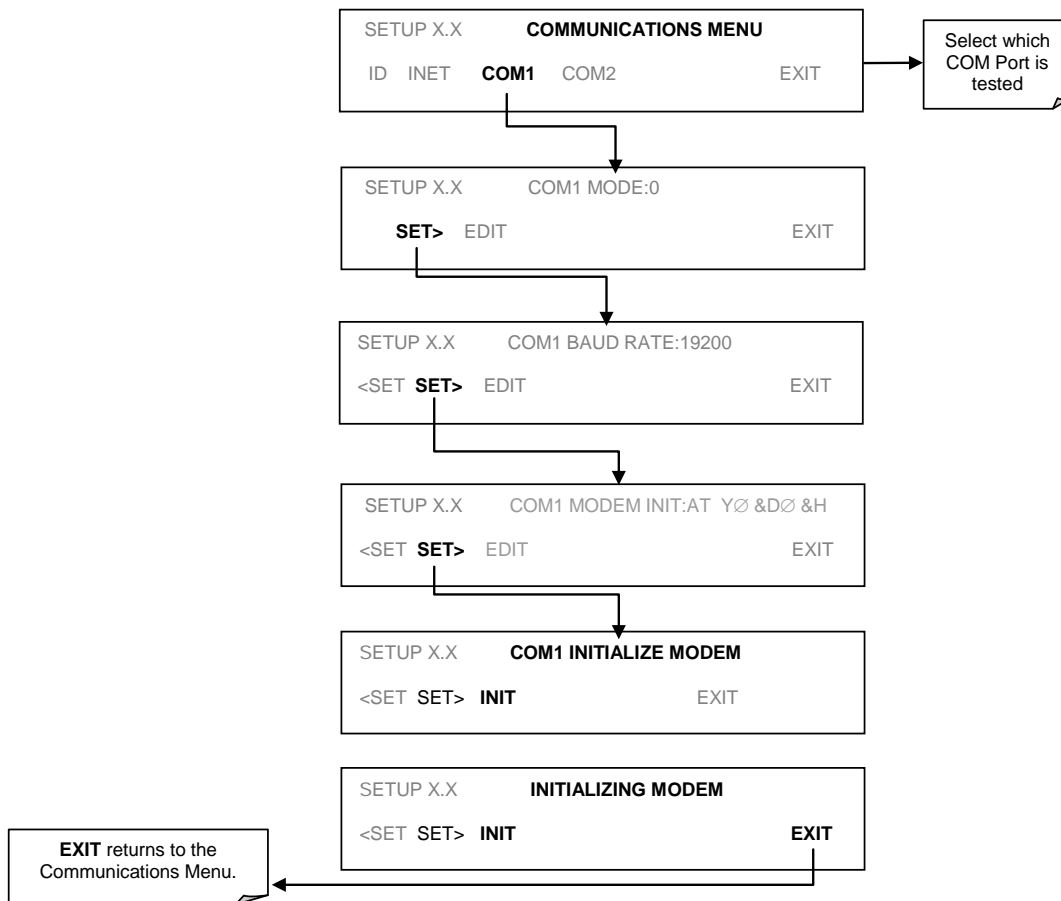


Figure 8-5: COMM – Initialize the Modem

## 8.4. COM PORT PASSWORD SECURITY

In order to provide security for remote access of the T100, 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** (refer to Section 5.5). 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 T100 analyzer with **SECURITY MODE** feature enabled, type:

```
LOGON 940331
```

940331 is the default password. To change the default password, use the variable RS-232\_PASS issued as follows:

```
V RS-232_PASS=NNNNNN
```

Where N is any numeral between 0 and 9.

## 8.5. ADDITIONAL COMMUNICATIONS DOCUMENTATION

**Table 8-5: Serial Interface Documents**

Interface / Tool	Document Title	Part Number	Available Online*
APICOM	APICOM User Manual	058130000	YES
DAS Manual	Detailed description of the DAS	028370000	YES

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

## 9. CALIBRATION PROCEDURES

This section describes the calibration procedures for the T100. All of the methods described in this section can be initiated and controlled through the COM ports.

### IMPORTANT

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#### IMPACT ON READINGS OR DATA

**If you are using the T100 for US-EPA controlled monitoring, refer to Section 0 for information on the EPA calibration protocol.**

---

### 9.1. CALIBRATION PREPARATIONS

The calibration procedures in this section assume that the analog range and units of measure, range mode, and reporting range have already been selected for the analyzer. If this has not been done, please do so before continuing (refer to Sections 3.4.4.1 and 5 for instructions).

### IMPORTANT

---

#### IMPACT ON READINGS OR DATA

**It is recommended that the LAMP CAL routine (refer to Section 5.9.6) be performed prior to all calibration operations. This will allow the instrument to account for minor changes due to aging of the UV lamp.**

---

#### 9.1.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the T100 analyzer requires specific equipment and supplies. These include, but are not limited to, the following:

- Zero-air source
- Sulfur dioxide span gas source
- Gas lines - all gas line materials should be Teflon-type or glass.
- A recording device such as a strip-chart recorder and/or data logger (optional).
- Traceability Standards

### 9.1.1.1. ZERO AIR

Zero air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. For SO<sub>2</sub> measuring devices, zero air should be similar in composition to the sample gas but devoid of SO<sub>2</sub> and large amounts of hydrocarbons, nitrogen oxide (NO) and with a water vapor dew point ≤ -15° C.

Devices such as the API Model 701 zero air generator that condition ambient air by drying and removal of pollutants are available. We recommend this type of device for generating zero air.

### 9.1.1.2. SPAN GAS

Span gas is specifically mixed to match the chemical composition of the gas being measured at about 80% of the desired full measurement range. For example, if the measurement range is 500 ppb, the span gas should have an SO<sub>2</sub> concentration of about 400 ppb.

Span gases should be certified to a specific accuracy to ensure accurate calibration of the analyzer. Typical gas accuracy for SO<sub>2</sub> gases is 1 or 2 %.

- If using a secondary dilution source with zero air through a calibrator, then use a bottle of SO<sub>2</sub> balanced nitrogen.
- If calibrator and zero air source are not available, then use a bottle of SO<sub>2</sub> balanced air.

Teledyne API offers an IZS option operating with permeation devices. The accuracy of these devices is about ±5%. Whereas this may be sufficient for quick, daily calibration checks, we strongly recommend using certified SO<sub>2</sub> span gases for accurate calibration.

### IMPORTANT

#### IMPACT ON READINGS OR DATA

**Applications requiring US-EPA equivalency do not allow permeation devices to be used as sources of span gas for calibration of the analyzer.**

### 9.1.1.3. CALIBRATION GAS STANDARDS AND 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.

**Table 9-1: NIST-SRM's Available for Traceability of SO<sub>2</sub> Calibration Gases**

NIST-SRM <sup>4</sup>	TYPE	NOMINAL CONCENTRATION
1693a	Sulfur dioxide in N <sub>2</sub>	50 ppm
1694a	Sulfur dioxide in N <sub>2</sub>	100 ppm
1661a	Sulfur dioxide in N <sub>2</sub>	500 ppm

## 9.1.2. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the T100'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 T100 provides an internal data acquisition system (DAS), which is described in detail in Section 7.

### IMPORTANT

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#### IMPACT ON READINGS OR DATA

**Be aware of the difference between Calibration and Calibration Check: Pressing the ENTR button during the following procedure re-calculates the stored values for OFFSET and SLOPE and alters the instrument's calibration. If you wish to perform a calibration CHECK, do not press ENTR and refer to Section 9.3.**

---

## 9.2. MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the T100 SO<sub>2</sub> analyzer.

**STEP ONE:** Connect the sources of zero air and span gas as shown below.

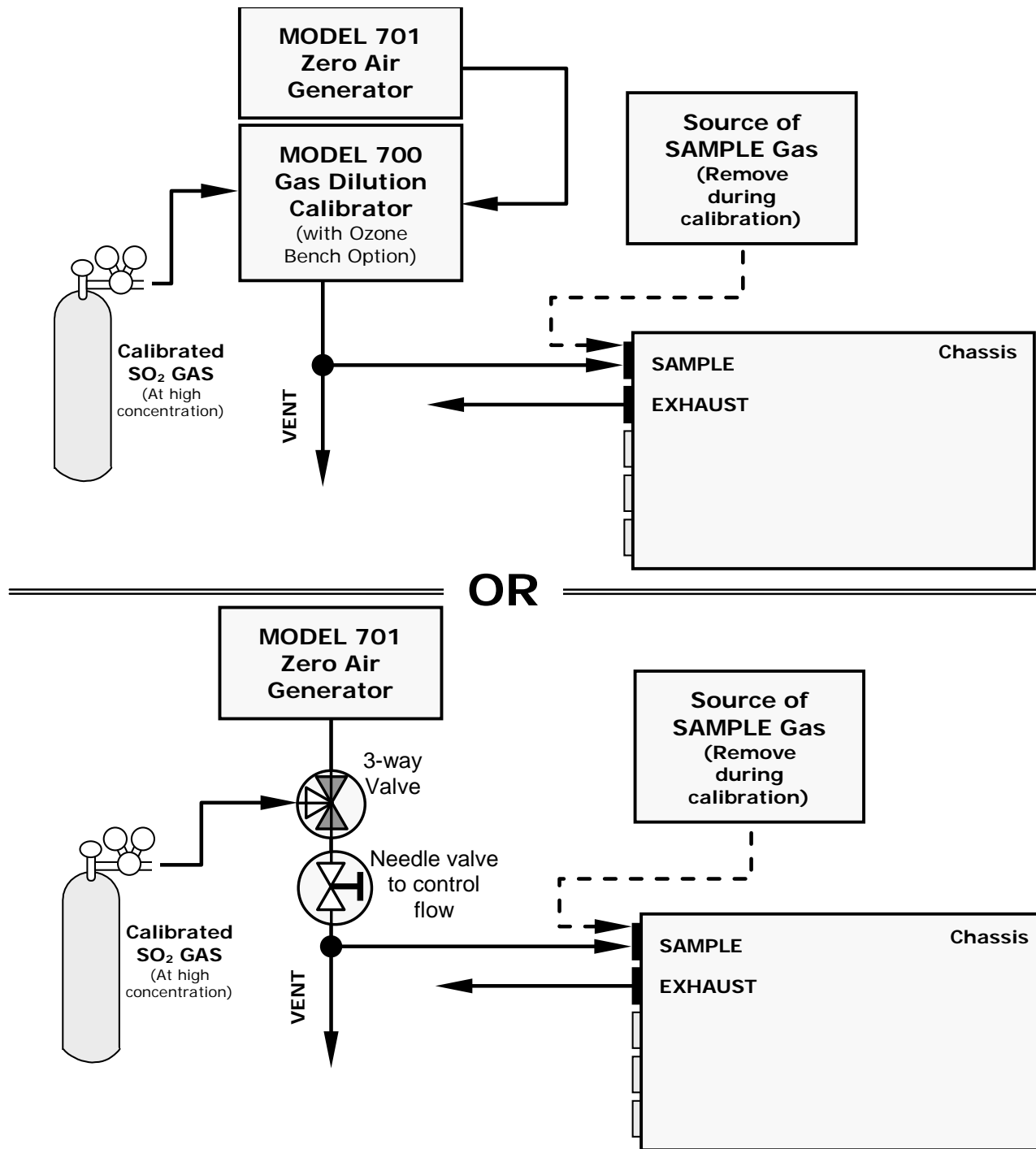
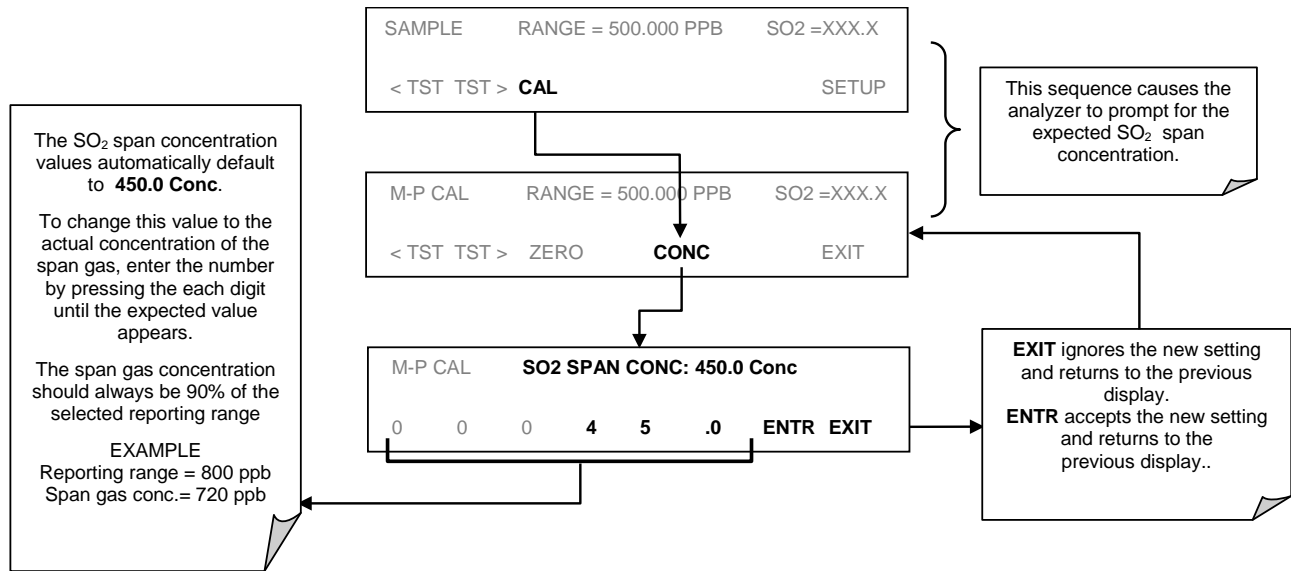


Figure 9-1: Setup for Manual Calibration without Z/S valve or IZS Option (Step 1)

**STEP TWO:** Set the expected SO<sub>2</sub> span gas concentrations. In this example the instrument is set for single (SNGL) range mode with a reporting range span of 500 ppb.



**Figure 9-2: Setup for Manual Calibration without Z/S valve or IZS Option (Step 2)**

**STEP THREE:** Perform the zero/span calibration:

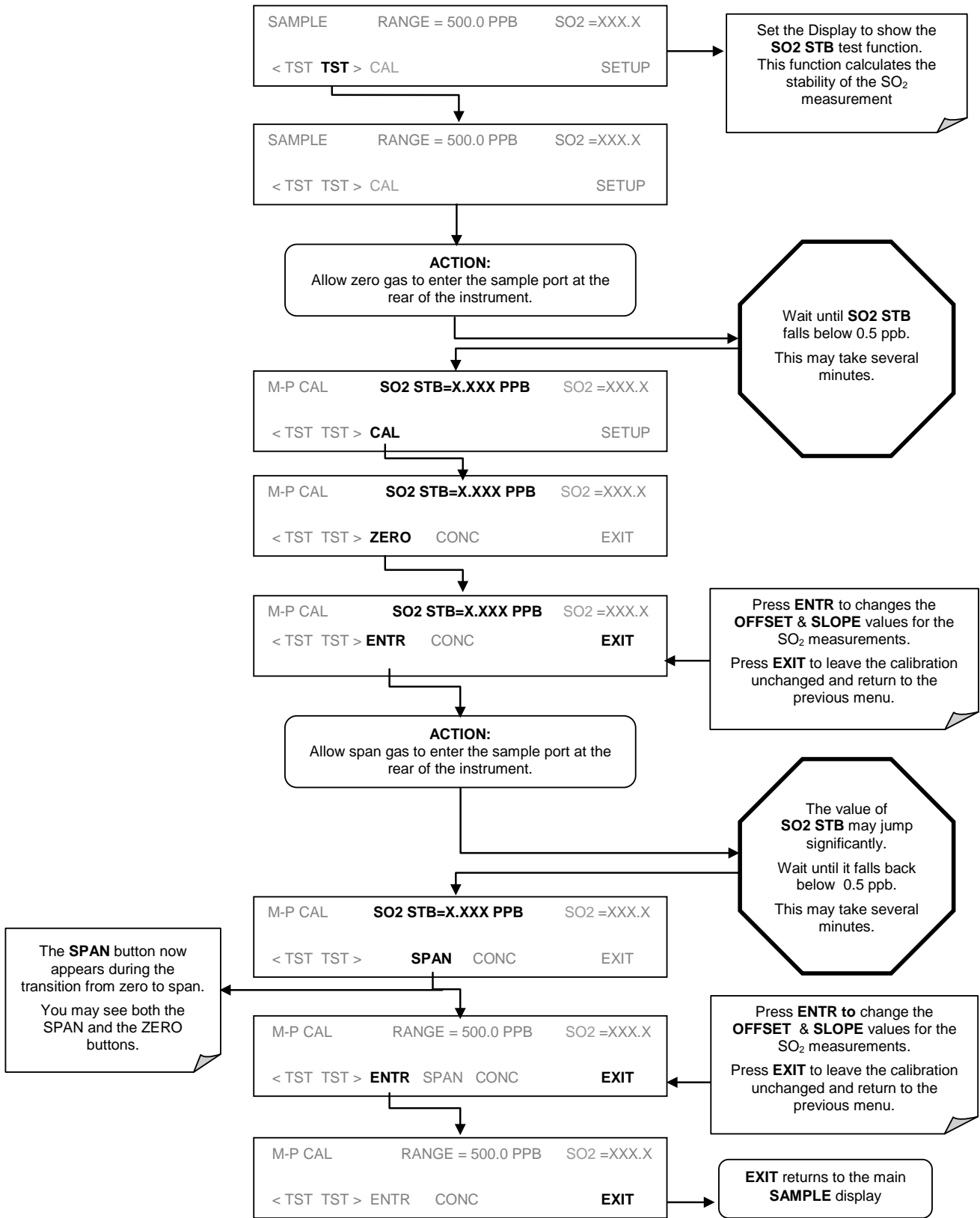


Figure 9-3: Setup for Manual Calibration without Z/S valve or IZS Option (Step 3)



**IMPORTANT**

**IMPACT ON READINGS OR DATA**

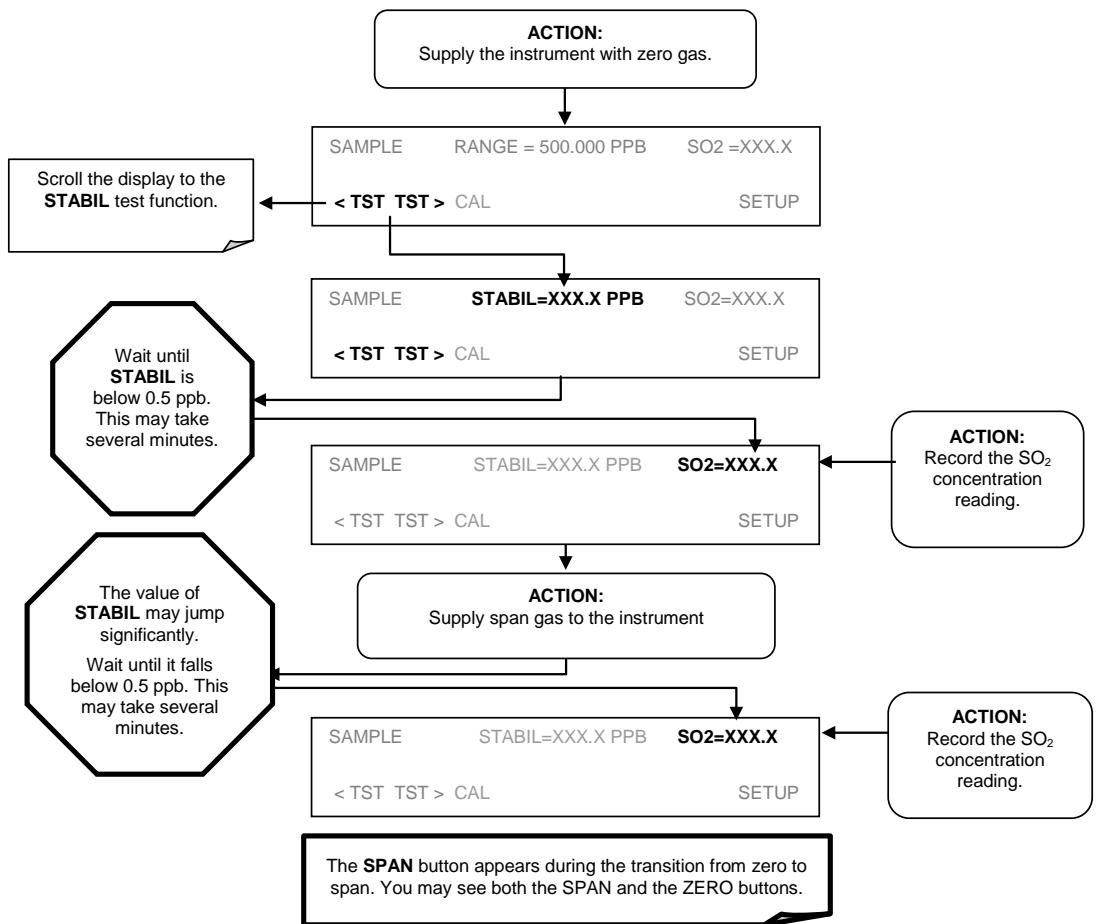
If the **ZERO** or **SPAN** buttons are not displayed during zero or span calibration, the measured concentration value is too different from the expected value and the analyzer does not allow zeroing or spanning the instrument. Refer to Section 11.4 for more information on calibration problems.

### 9.3. MANUAL CALIBRATION CHECKS

Informal calibration checks will only evaluate the analyzer's response curve, but do not alter it. It is recommended as a regular maintenance item, to perform calibration checks in order to monitor the analyzer's performance. To carry out a calibration check rather than a full calibration, perform the following procedures:

**STEP ONE:** Connect the sources of zero air and span gas as shown in Figure 9-1.

**STEP TWO:** Perform the zero/span calibration check procedure:



**Figure 9-4: Setup for Manual Calibration Checks**

## 9.4. MANUAL CALIBRATION WITH ZERO/SPAN VALVES

Zero and Span calibrations using the Zero/Span Valve option are similar to that described in Section 9.2, except that:

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

**STEP ONE:** Connect the sources of zero air and span gas to the respective ports on the rear panel (refer to Figure 3-4) as shown below.

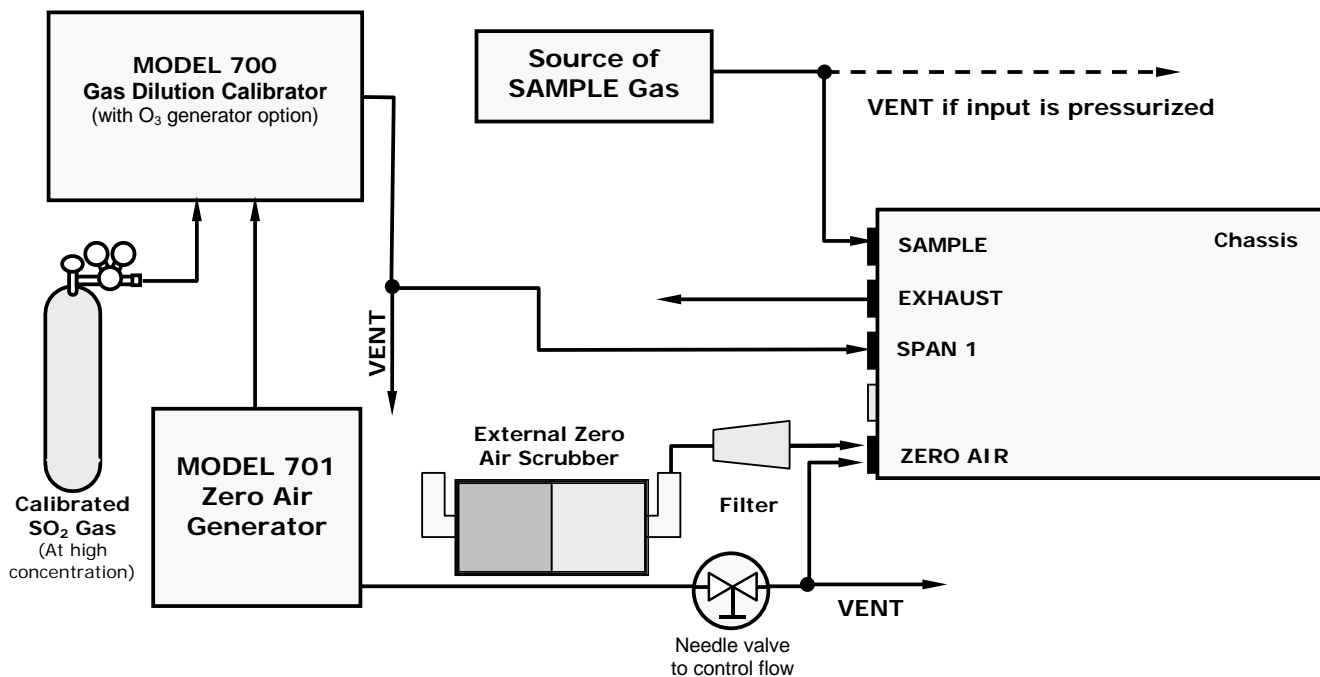
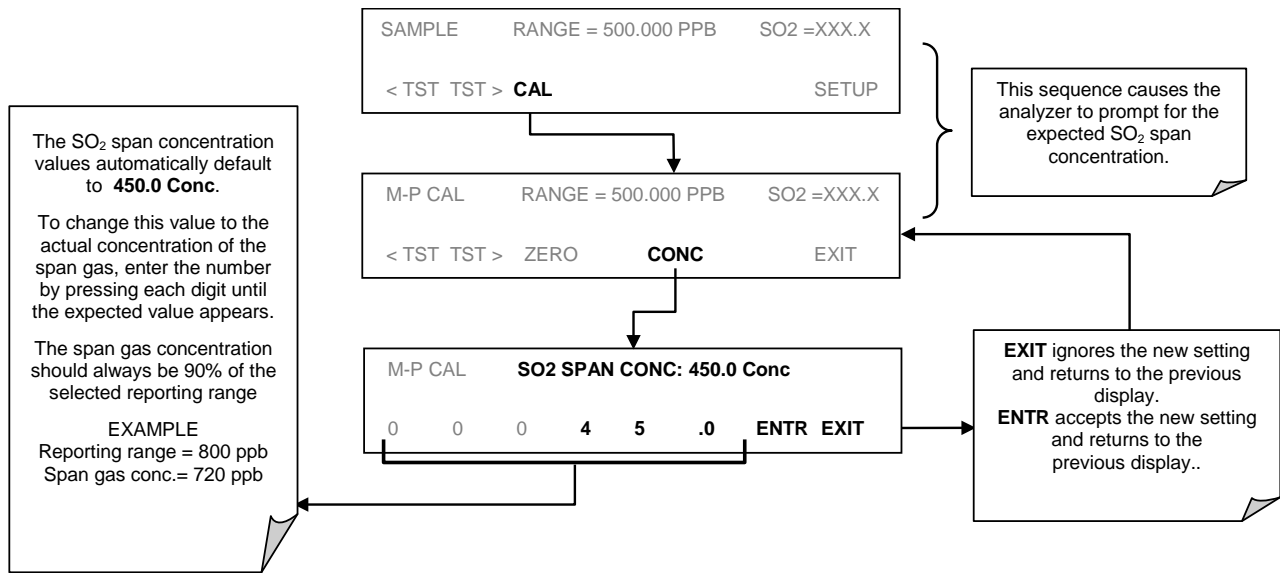


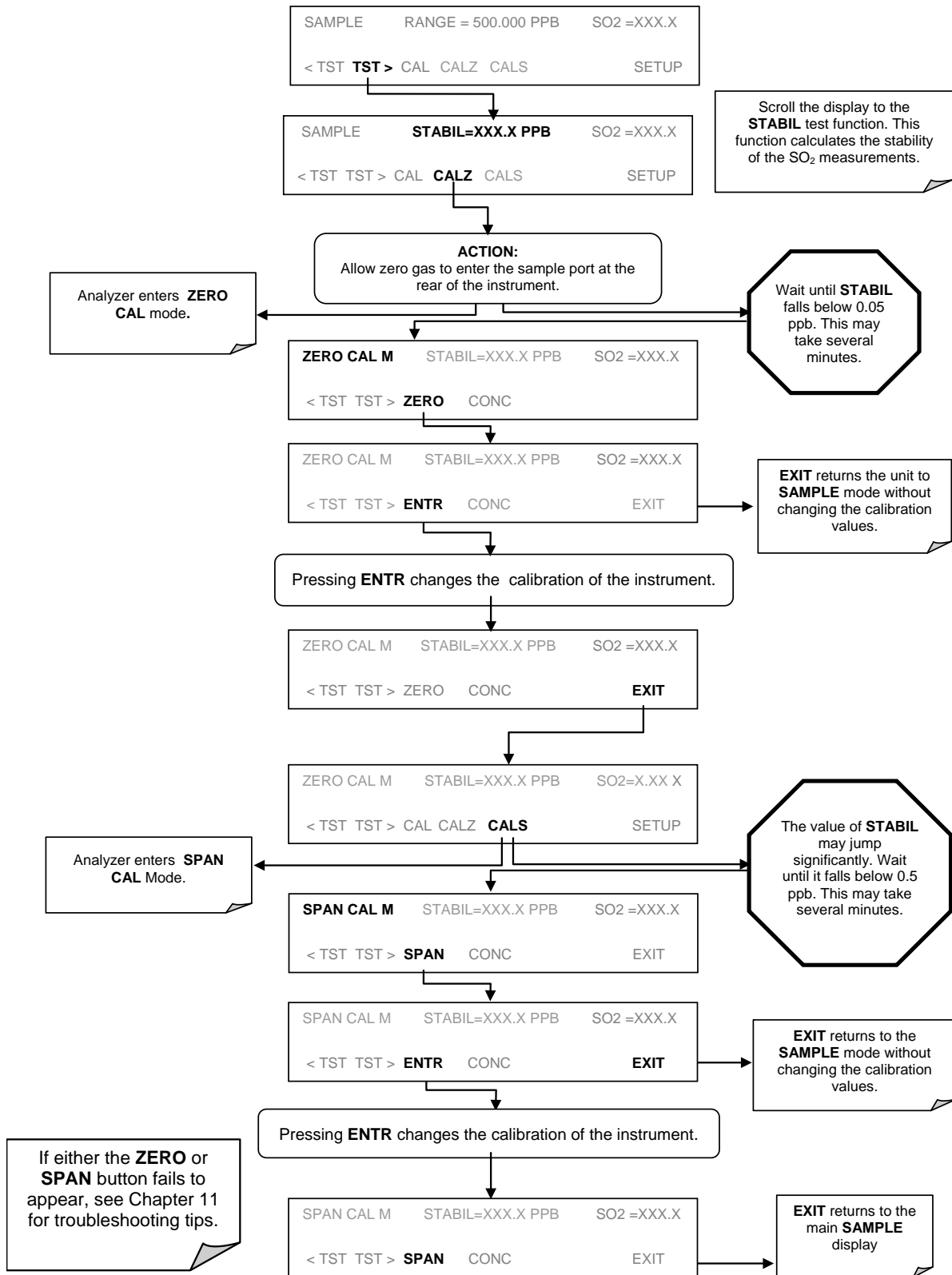
Figure 9-5: Setup for Manual Calibration with Z/S Valve Option Installed (Step 1)

**STEP TWO: Set the expected SO<sub>2</sub> span gas value:**



**Figure 9-6: Setup for Manual Calibration with Z/S Valve Option Installed (Step 2)**

**Step Three:** Perform the calibration or calibration check according to the following flow chart:



**Figure 9-7: Setup for Manual Calibration with Z/S Valve Option Installed (Step 3)**

## 9.5. MANUAL CALIBRATION WITH IZS OPTION

Under the best conditions, the accuracy off the SO<sub>2</sub> effusion rate of the IZS option's permeation tube is about ±5%. This can be subject to significant amounts of drift as the tube ages and the amount of SO<sub>2</sub> contained in the tube is depleted. Whereas this may be sufficient for informal calibration checks, it is not adequate for formal calibrations and is not approved for use by the US EPA as a calibration source.

Therefore, for formal calibrations of an instrument with an IZS option installed the following provisions must be followed.

- Zero air and span gas must be supplied to the analyzer through the sample gas inlet as depicted in Figure 9-1 of Section 9.2.
- The calibration procedure must be initiated using the **CAL** button, not the **CALZ** or **CALS** buttons, using the procedure defined in Section 9.2.
- Using the **CAL** button does not activate the zero/span or sample/cal valves of the IZS option, thus allowing the introduction of zero air and sample gas through the sample port from more accurate, external sources such as a calibrated bottle of SO<sub>2</sub> or a Model T700 Dilution Calibrator.

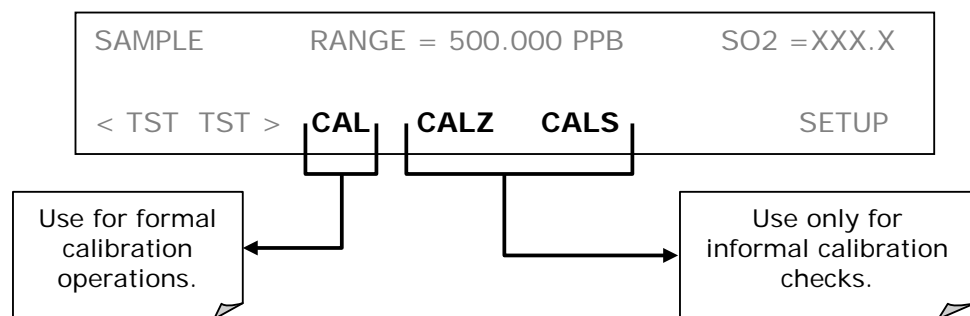


Figure 9-8: Manual Calibration with IZS Option

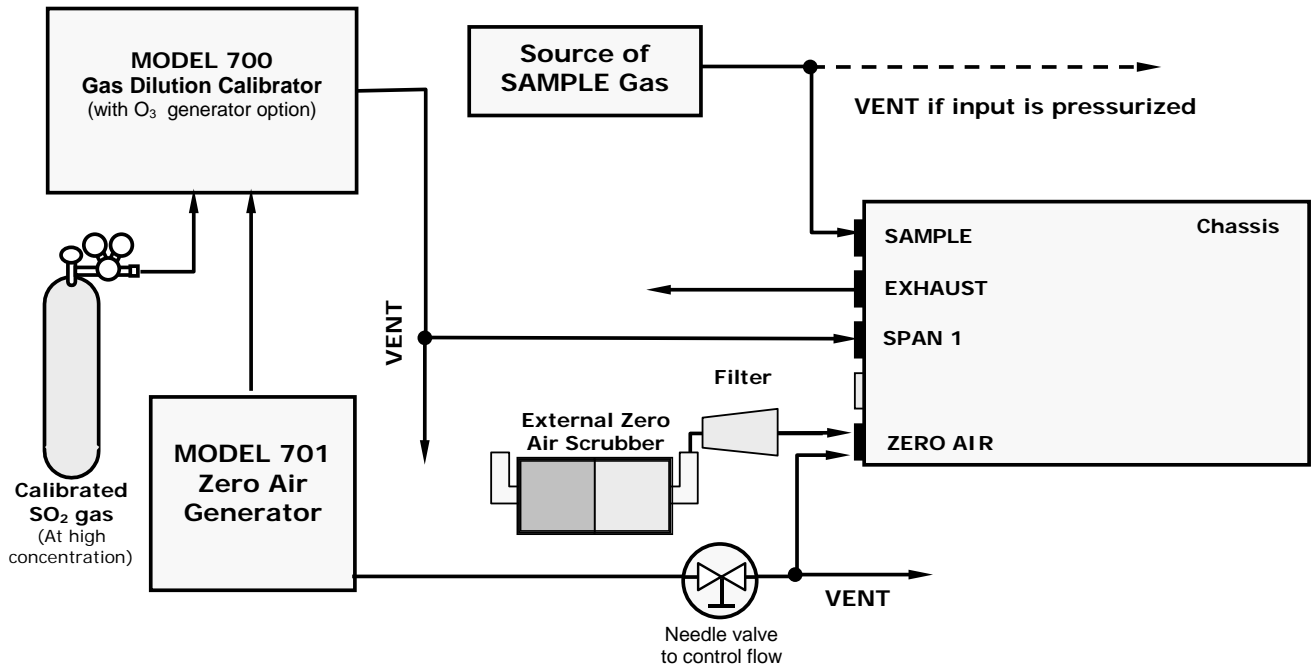
## 9.6. MANUAL CALIBRATION CHECKS WITH IZS OR ZERO/SPAN VALVES

Zero and span checks using the zero/span valve or IZS option are similar to that described in Section 9.3, with the following exceptions:

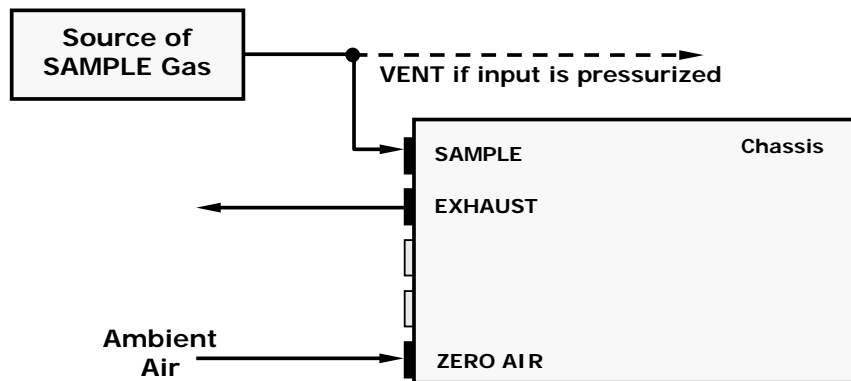
- On units with an IZS option installed, zero air and span gas are supplied to the analyzer through the zero gas inlet and from ambient air.
- On units with a zero/span valve option installed, zero air and span gas are supplied to the analyzer through the zero gas and span gas inlets from two different sources.
- The zero and calibration operations are initiated directly and independently with dedicated buttons **CALZ** and **CALS**.

To perform a manual calibration check of an analyzer with a zero/span valve or IZS Option installed, use the following method:

**STEP ONE:** Connect the sources of Zero Air and Span Gas as shown below.

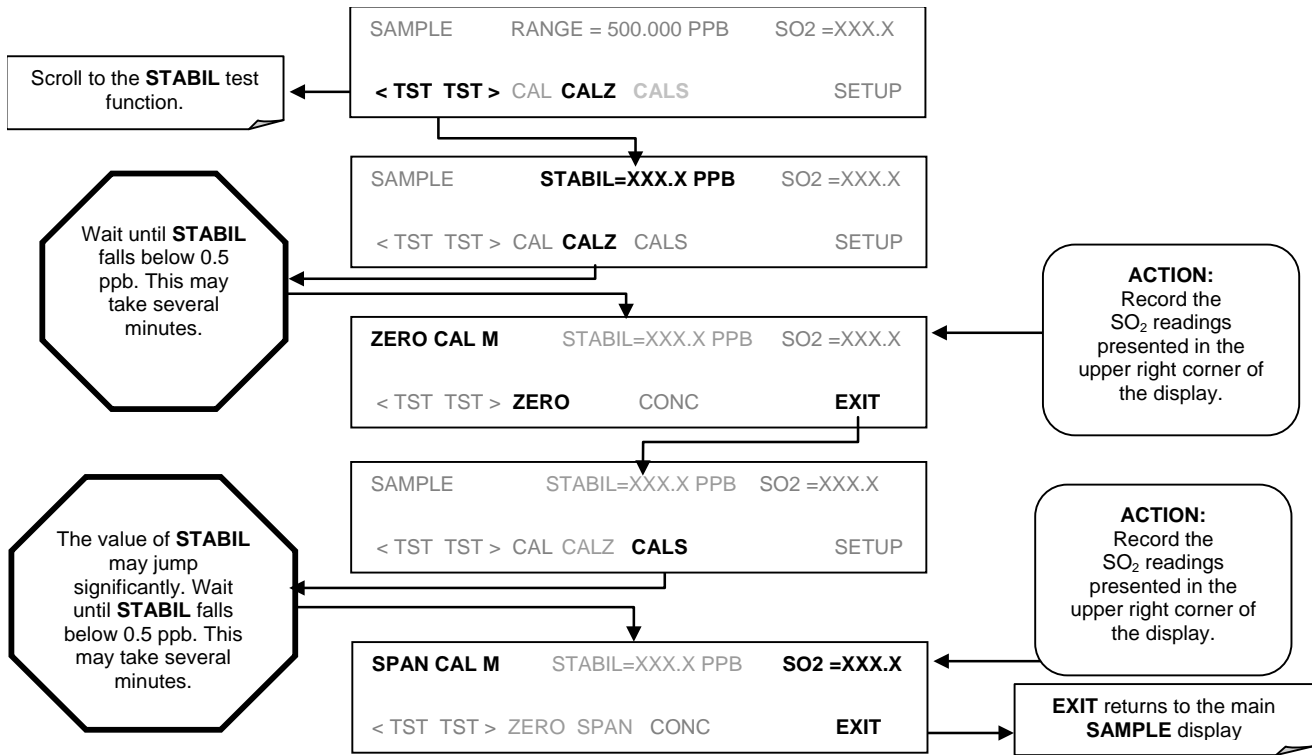


**Internal Zero/Span Option (IZS) – Option 51A**



**Figure 9-9: Setup for Manual Calibration Check with Z/S Valve or IZS Option (Step 1)**

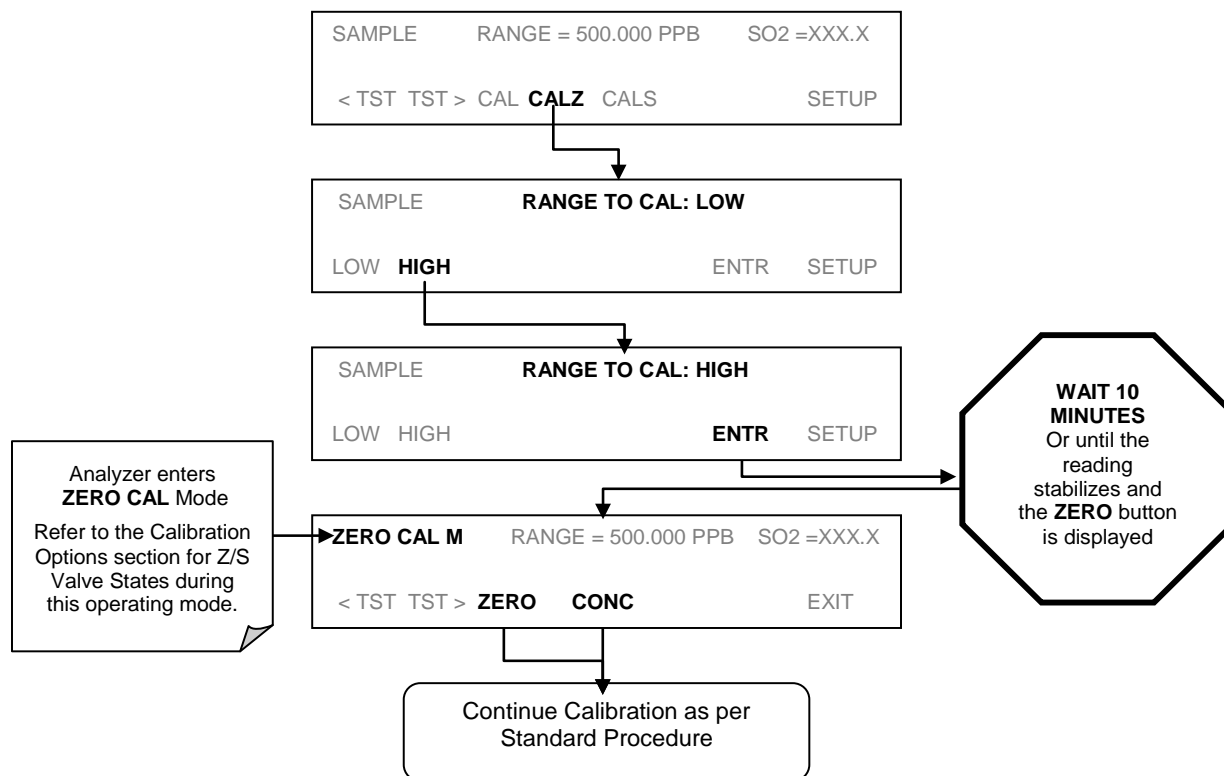
**STEP TWO: Perform the zero/span check.**



**Figure 9-10: Setup for Manual Calibration Check with Z/S Valve or IZS Option (Step 2)**

## 9.7. MANUAL CALIBRATION IN DUAL OR AUTO REPORTING RANGE MODES

When the analyzer is in either Dual or Auto Range modes the user must run a separate calibration procedure for each range. After pressing the **CAL**, **CALZ** or **CALS** buttons the user is prompted for the range that is to be calibrated as seen in the **CALZ** example below:



**Figure 9-11: Manual Calibration in Dual/Auto Reporting Range Modes**

Once this selection is made, the calibration procedure continues as previously described in Sections 9.2 through 9.6. The other range may be calibrated by starting over from the main **SAMPLE** display.

### 9.7.1. CALIBRATION WITH REMOTE CONTACT CLOSURES

Contact closures for controlling calibration and calibration checks are located on the rear panel **CONTROL IN** connector. Instructions for setup and use of these contacts can be found in Section 8.1.2.

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



If contact closures are used in conjunction with the analyzer's AutoCal (refer to Section 9.8) feature and the AutoCal attribute **CALIBRATE** is enabled, the T100 will not recalibrate the analyzer until the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to **SAMPLE** mode.

If the AutoCal attribute **CALIBRATE** is disabled, the instrument will return to **SAMPLE** mode, leaving the instrument's internal calibration variables unchanged.

## 9.8. AUTOMATIC CALIBRATION (AUTOCAL)

The AutoCal system allows unattended, periodic operation of the zero/span valve options by using the analyzer's internal time of day clock. AutoCal operates by executing user-defined sequences to initiate the various calibration modes of the analyzer and to open and close valves appropriately. It is possible to program and run up to three separate sequences (**SEQ1**, **SEQ2** and **SEQ3**). Each sequence can operate in one of three modes or be disabled.

**Table 9-2: AutoCal Modes**

MODE	ACTION
<b>DISABLED</b>	Disables the sequence
<b>ZERO</b>	Causes the sequence to perform a zero calibration or check
<b>ZERO-SPAN</b>	Causes the sequence to perform a zero and span concentration calibration or check
<b>SPAN</b>	Causes the sequence to perform a span concentration calibration or check

Each mode has seven setup parameters (Table 9-3) that control operational details of the sequence.

**Table 9-3: AutoCal Attribute Setup Parameters**

PARAMETER	ACTION
<b>Timer Enabled</b>	Turns on the Sequence timer
<b>Starting Date</b>	Sequence will operate on Starting Date
<b>Starting Time</b>	Sequence will operate at Starting Time <sup>1, 2</sup>
<b>Delta Days</b>	Number of days to skip between each sequence
<b>Delta Time</b>	Incremental delay on each Delta Day that the sequence starts.
<b>Duration</b>	Duration of the sequence in minutes
<b>Calibrate</b>	Enable to do dynamic zero/span calibration, disable to do a cal check only. This must be set to OFF for units used in US EPA applications and with IZS option installed.
<sup>1</sup> The programmed <b>STARTING_TIME</b> must be a minimum of 5 minutes later than the real time clock (refer to Section 5.6 for setting real time clock). <sup>2</sup> Avoid setting two or more sequences at the same time of the day. Any new sequence which is initiated whether from a timer, the <b>COMM</b> ports, or the contact closure inputs will override any sequence which is in progress.	

### Note

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**If at any time an inapplicable entry is selected e.g., Delta Days > 367, the ENTR button will disappear from the display.**  
 -----

Note

The CALIBRATE attribute must always be set to OFF for analyzers used in US EPA controlled applications that have IZS option installed.  
Calibration of instruments used in US EPA related applications should only be performed using external sources of zero air and span gas with an accuracy traceable to EPA or NIST standards and supplied through the analyzer's sample port (refer to Section 9.2).

The following example sets Sequence 2 to carry out a zero-span calibration every other day starting at 01:00 on June 4, 2015, lasting 15 minutes. This sequence will start 0.5 hours later each day that it is run.

Table 9-4: Example Auto-Cal Sequence

MODE / ATTRIBUTE	VALUE	COMMENT
SEQUENCE	2	Define Sequence #2
MODE	ZERO-SPAN	Select Zero and Span Mode
TIMER ENABLE	ON	Enable the timer
STARTING DATE	04-JUN-15	Start after June 4, 2015
STARTING TIME	01:00	First Span starts at 01:00
DELTA DAYS	2	Run Sequence #2 every other day
DELTA TIME	00:30	Run Sequence #2 0.5 h later each scheduled day
DURATION	15.0	Operate Span valve for 15 min
CALIBRATE	ON	The instrument will re-set the slope and offset values for the SO <sub>2</sub> channel at the end of the AutoCal sequence

To program the sample sequence shown in Table 9-4:

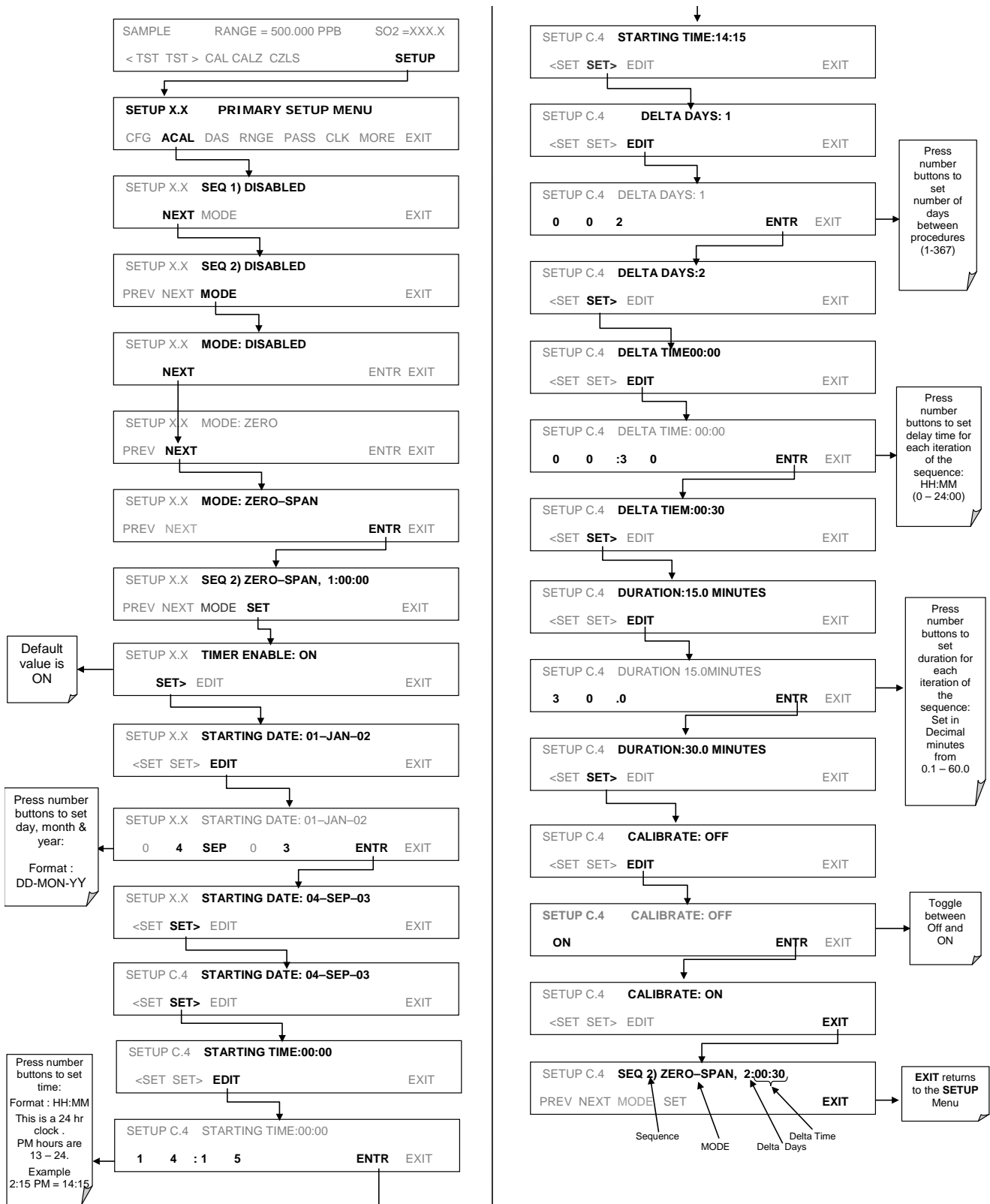


Figure 9-12: AUTO CAL – User Defined Sequence

With dynamic calibration turned on, the state of the internal setup variables **DYN\_SPAN** and **DYN\_ZERO** is set to **ON** and the instrument will reset the slope and offset values for the SO<sub>2</sub> response each time the AutoCal program runs. This continuous re-adjustment of calibration parameters can often mask subtle fault conditions in the analyzer. It is recommended that, if dynamic calibration is enabled, the analyzer's test functions, slope and offset values be checked frequently to assure high quality and accurate data from the instrument.

## 9.9. CALIBRATION QUALITY

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer. The values for these terms, both individually and relative to each other, indicate the quality of the calibration. To perform this quality evaluation, you will need to record the values of both test functions (refer to Section 4.1.1 or Appendix A), all of which are automatically stored in the DAS channel **CALDAT** for data analysis, documentation and archival.

Ensure that these parameters are within the limits listed in the following table:

**Table 9-5: Calibration Data Quality Evaluation**

FUNCTION	MINIMUM VALUE	OPTIMUM VALUE	MAXIMUM VALUE
<b>SLOPE</b>	-0.700	1.000	1.300
<b>OFFS</b>	50.0 mV	n/a	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 troubleshooting in Section 11.

## 9.10. CALIBRATION OF OPTIONAL SENSORS

This section presents calibration procedures for the O<sub>2</sub> sensor option and for the CO<sub>2</sub> sensor option.

### 9.10.1. O<sub>2</sub> SENSOR CALIBRATION

Calibration begins with connecting the zero and span gases, then setting the concentration values.

#### 9.10.1.1. O<sub>2</sub> CALIBRATION SETUP

Bottled gases are connected as follows:

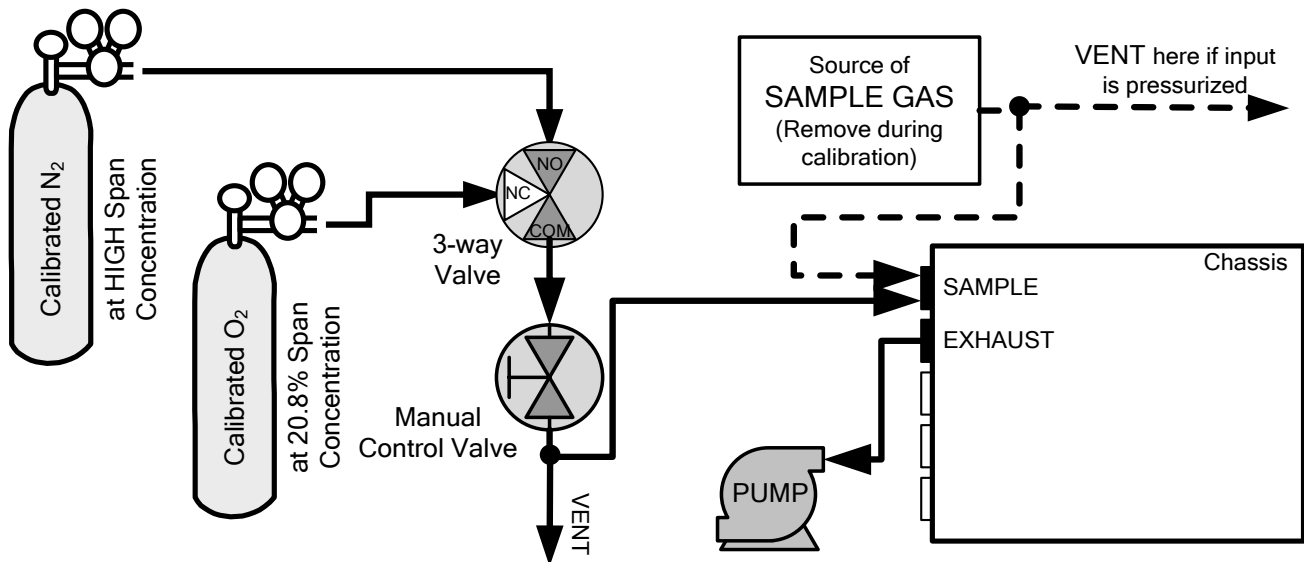


Figure 9-13: O<sub>2</sub> Sensor Calibration Set Up

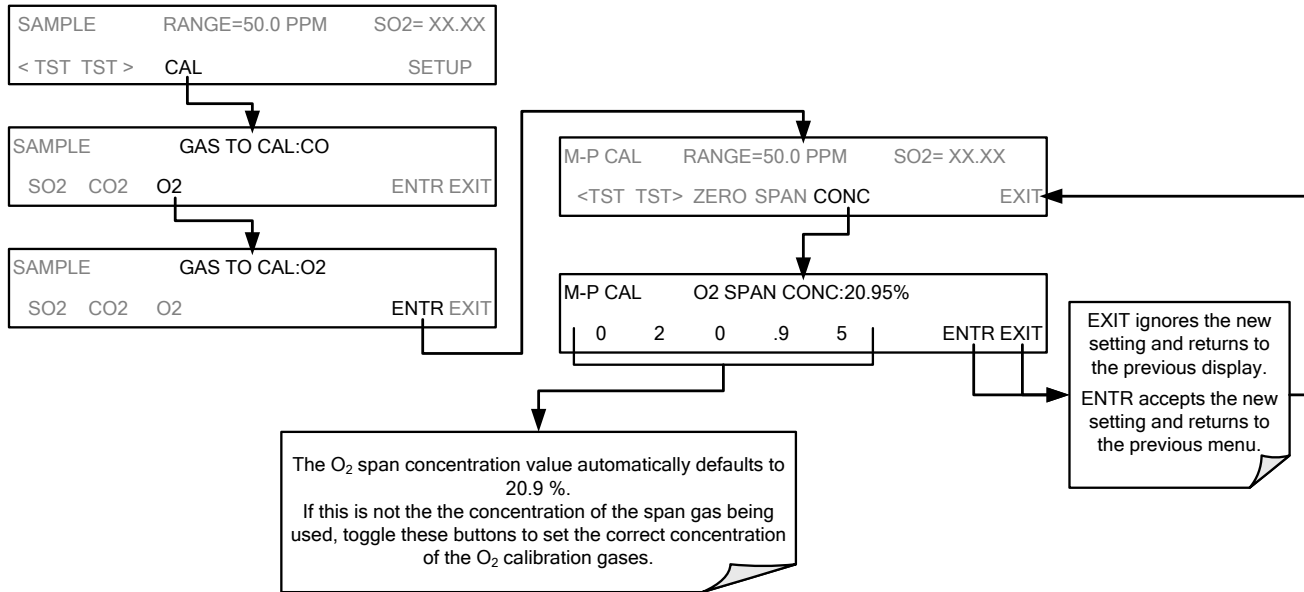
**O<sub>2</sub> SENSOR ZERO GAS:** Teledyne API recommends using pure N<sub>2</sub> when calibrating the zero point of your O<sub>2</sub> sensor option.

**O<sub>2</sub> SENSOR SPAN GAS:** Teledyne API recommends using 20.9% O<sub>2</sub> in N<sub>2</sub> when calibrating the span point of your O<sub>2</sub> sensor.

#### 9.10.1.2. SET O<sub>2</sub> SPAN GAS CONCENTRATION

Set the expected O<sub>2</sub> span gas concentration.

This should be equal to the percent concentration of the O<sub>2</sub> span gas of the selected reporting range (default factory setting = 20.9%; the approximate O<sub>2</sub> content of ambient air).



**Figure 9-14: O<sub>2</sub> Span Gas Concentration Set Up**

### 9.10.1.3. ACTIVATE O<sub>2</sub> SENSOR STABILITY FUNCTION

To change the stability test function from SO<sub>2</sub> concentration to the O<sub>2</sub> sensor output, press:

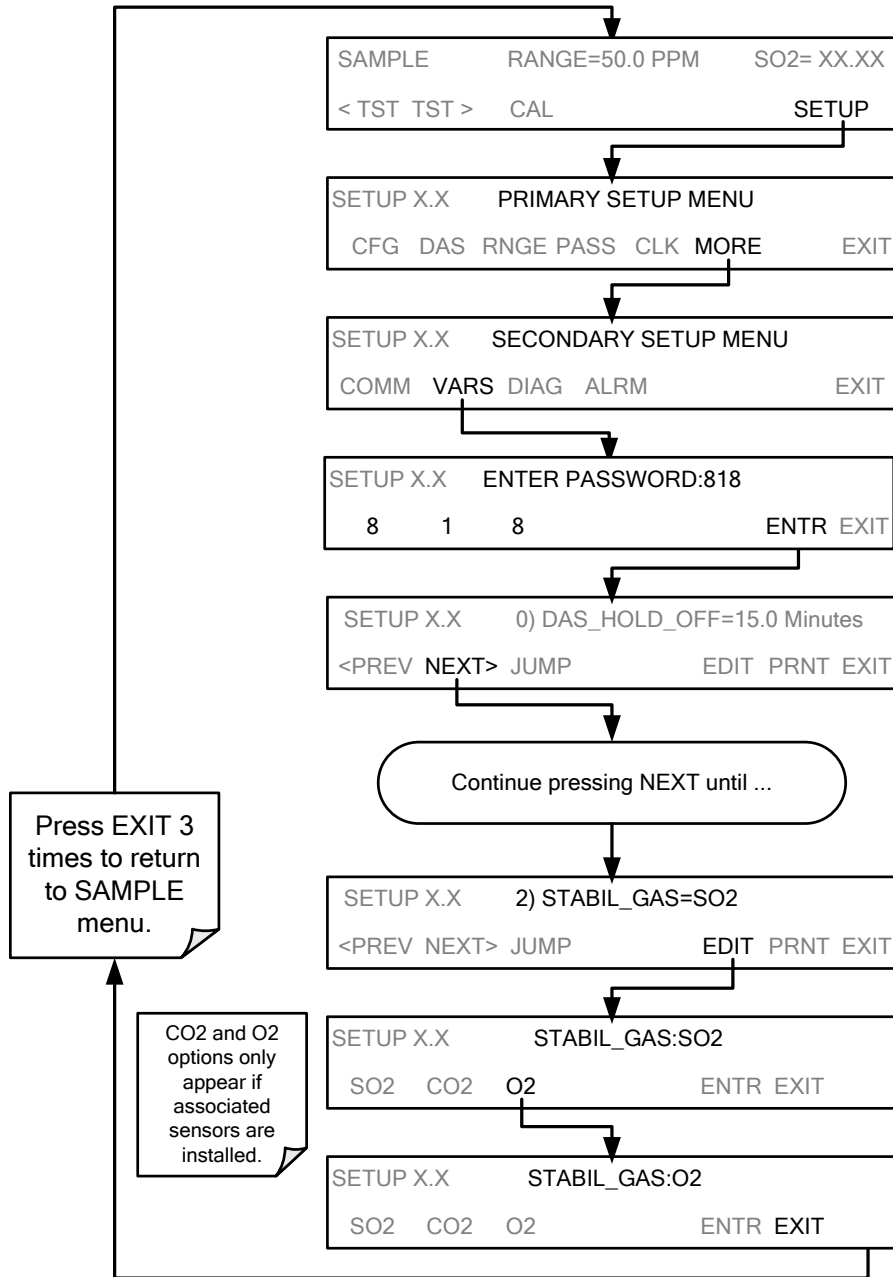


Figure 9-15: Activate O<sub>2</sub> Sensor Stability Function

#### IMPORTANT

#### IMPACT ON READINGS OR DATA

Use the same procedure to reset the STB test function to SO<sub>2</sub> when the O<sub>2</sub> calibration procedure is complete.

### 9.10.1.4. O<sub>2</sub> ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure:

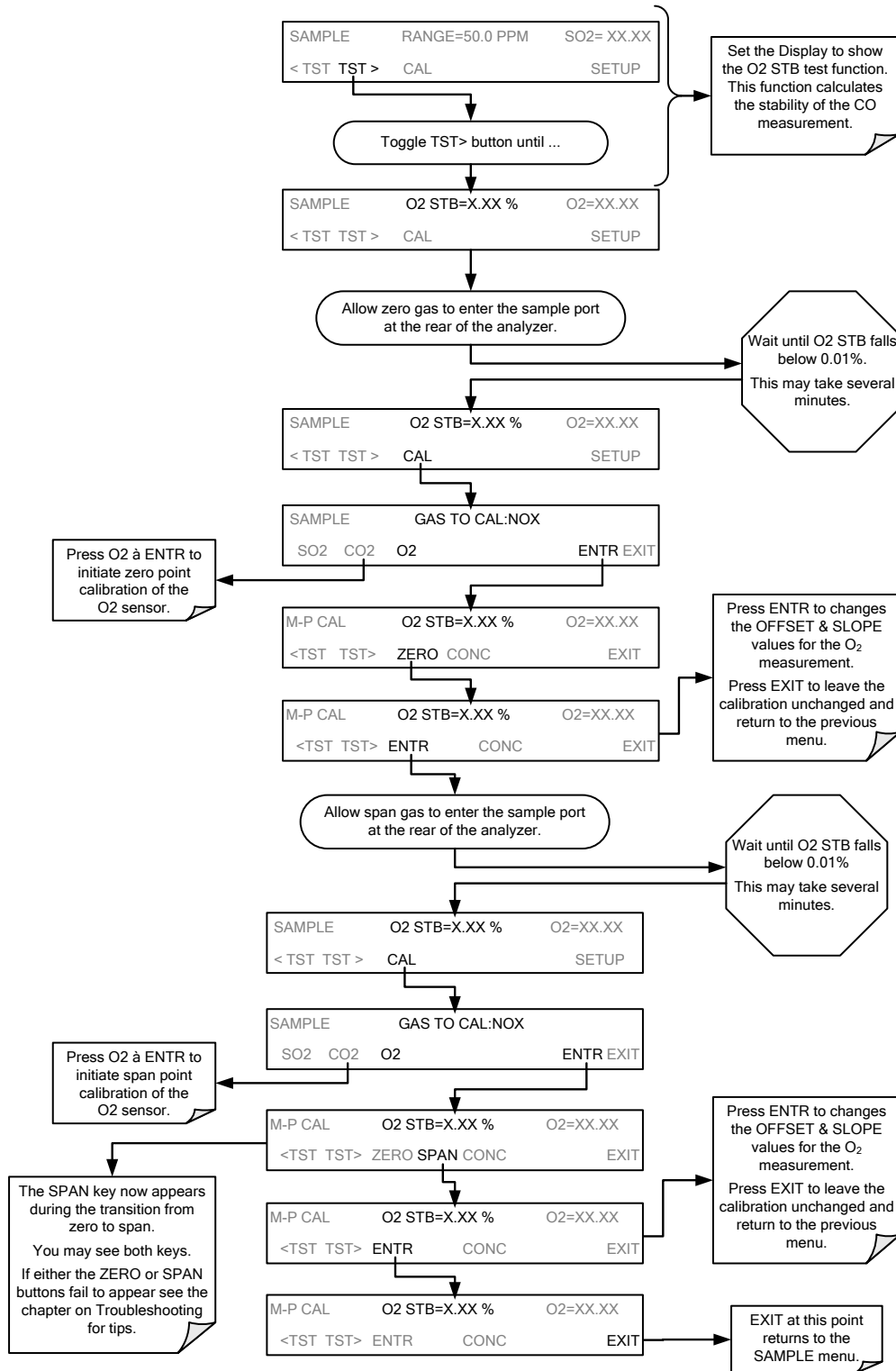


Figure 9-16: O<sub>2</sub> Zero/Span Calibration



## 9.10.2. CO<sub>2</sub> SENSOR CALIBRATION

Calibration begins with connecting the zero and span gases, then setting the concentration values.

### 9.10.2.1. CO<sub>2</sub> CALIBRATION SETUP

Bottled gases are connected as follows:

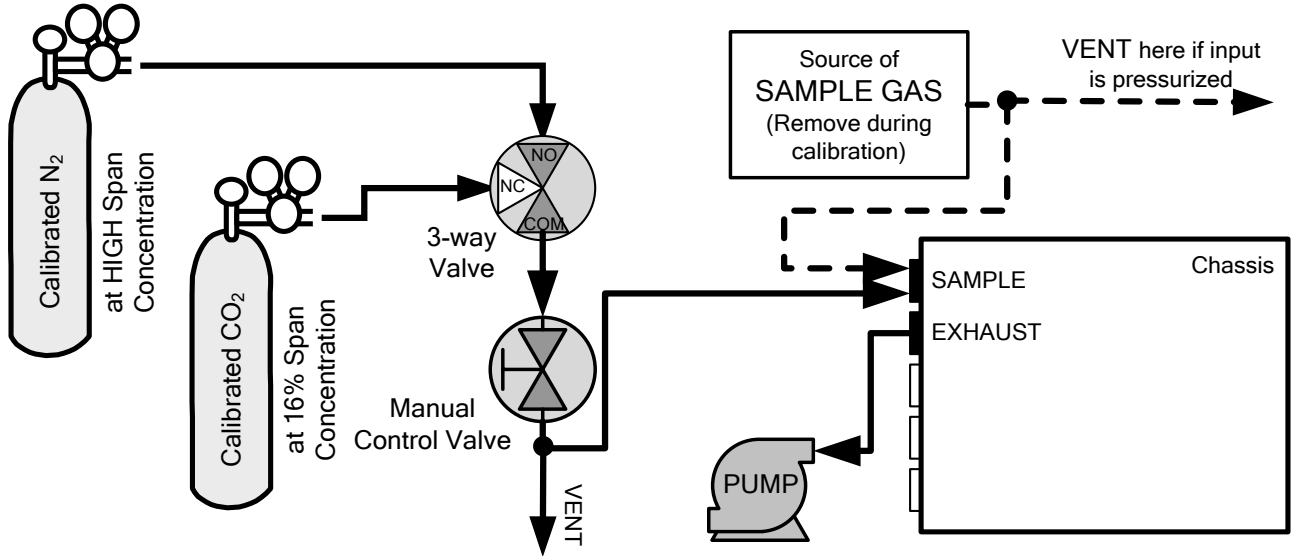


Figure 9-17: CO<sub>2</sub> Sensor Calibration Set Up

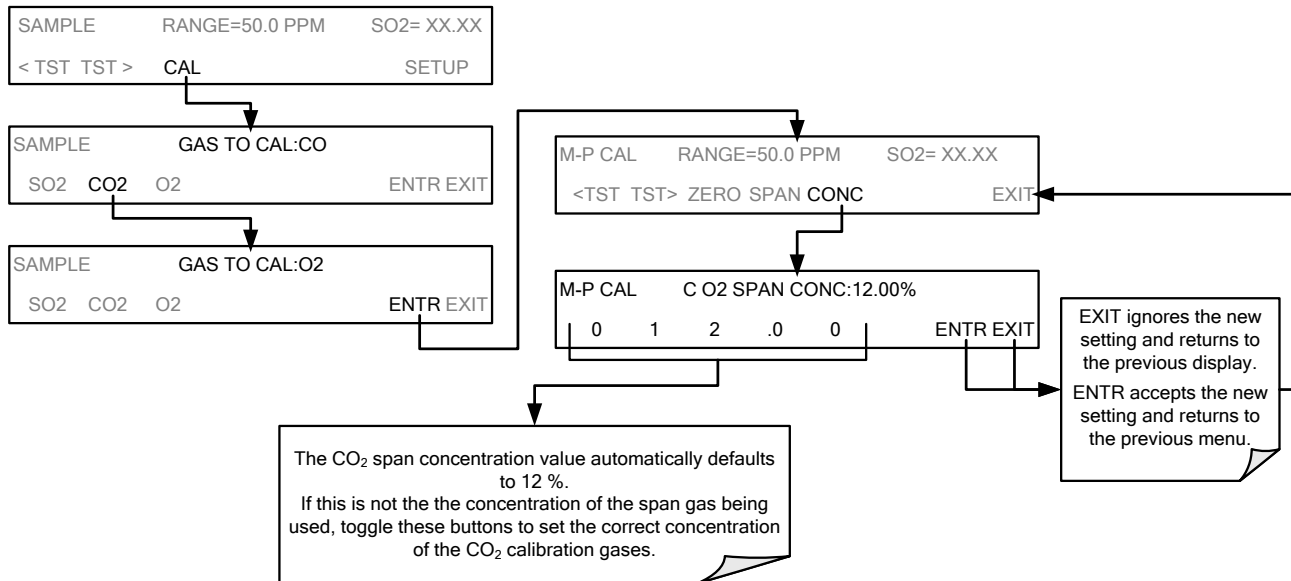
**CO<sub>2</sub> SENSOR ZERO GAS:** Teledyne API recommends using pure N<sub>2</sub> when calibration the zero point of your CO<sub>2</sub> sensor option.

**CO<sub>2</sub> SENSOR SPAN GAS:** Teledyne API recommends using 16% CO<sub>2</sub> in N<sub>2</sub> when calibration the span point of your CO<sub>2</sub> sensor is 20%.

### 9.10.2.2. SET CO<sub>2</sub> SPAN GAS CONCENTRATION

Set the expected CO<sub>2</sub> span gas concentration.

This should be equal to the percent concentration of the CO<sub>2</sub> span gas of the selected reporting range (default factory setting = 12%).



**Figure 9-18: CO<sub>2</sub> Span Gas Concentration Setup**

### 9.10.2.3. ACTIVATE CO<sub>2</sub> SENSOR STABILITY FUNCTION

To change the stability test function from SO<sub>2</sub> concentration to the CO<sub>2</sub> sensor output, press:

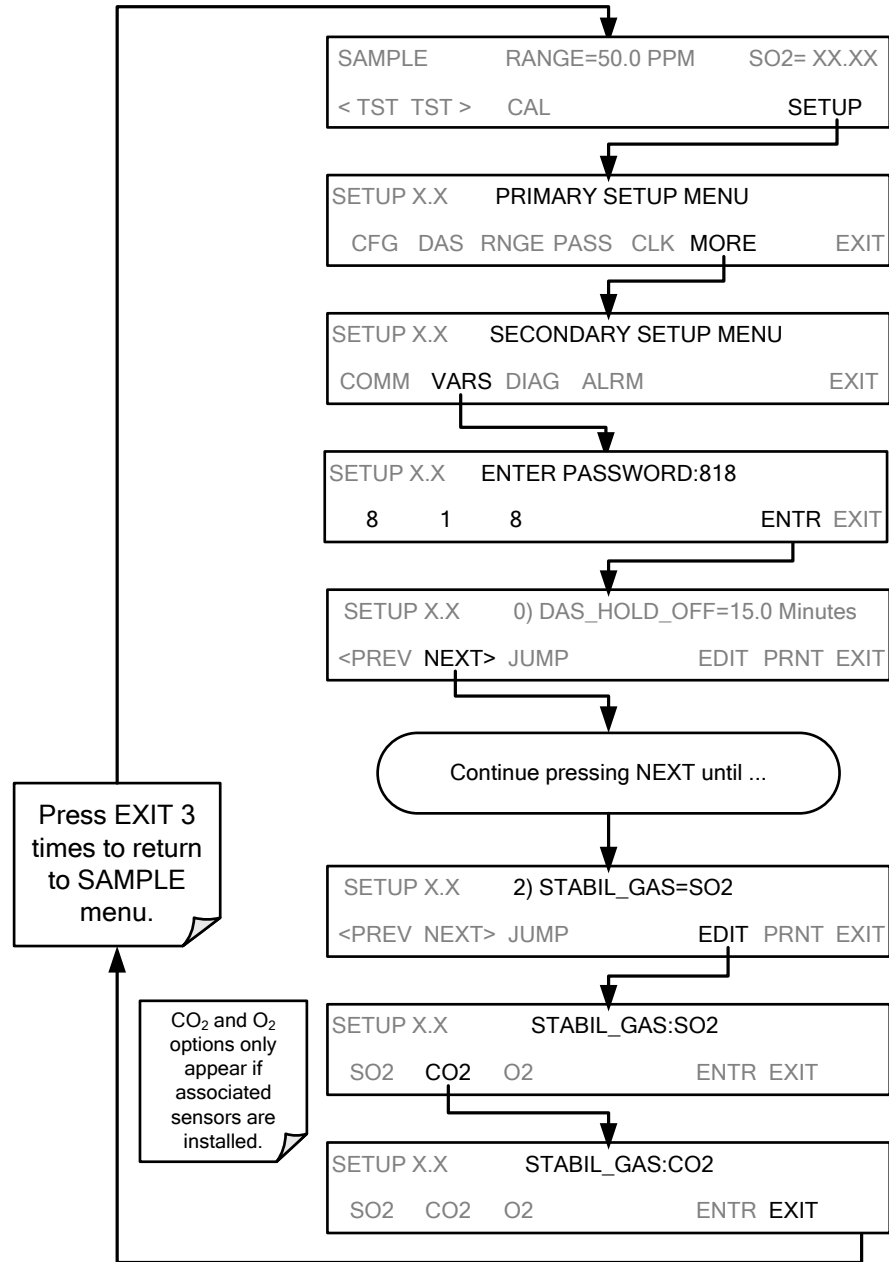


Figure 9-19: Activate CO<sub>2</sub> Sensor Stability Function

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

Use the same procedure to reset the STB test function to SO<sub>2</sub> when the CO<sub>2</sub> calibration procedure is complete.

### 9.10.2.4. CO<sub>2</sub> ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure:

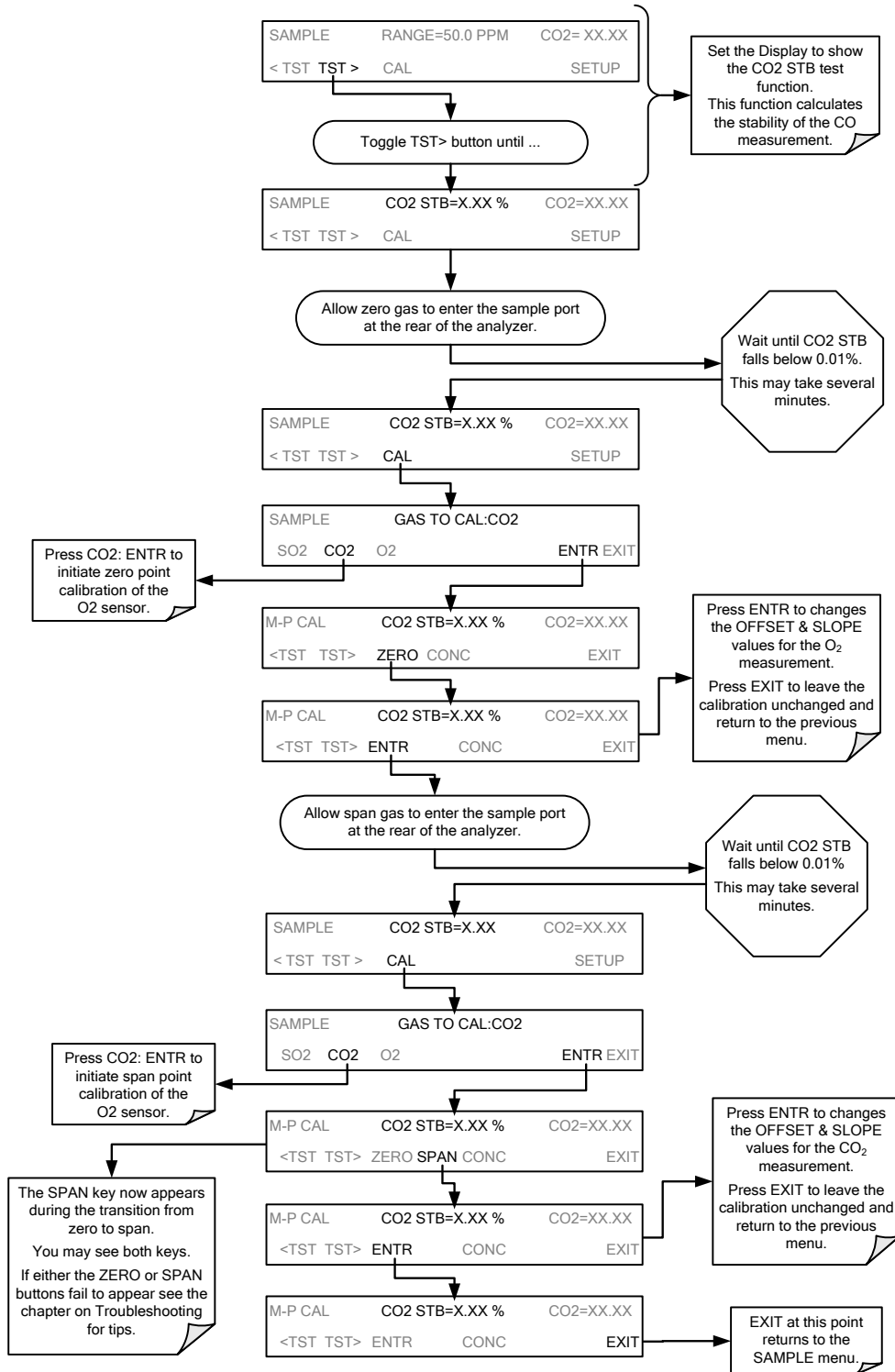


Figure 9-20: CO<sub>2</sub> Zero/Span Calibration

## 9.11. EPA PROTOCOL CALIBRATION

If the T100 is to be used for U.S. EPA SLAMS monitoring, always calibrate it prior to use, adhering to the EPA designation conditions for operation. (The official List of Designated Reference and Equivalent Methods is published in the U.S. Federal Register: <http://www3.epa.gov/ttn/amtic/criteria.html>). Pay strict attention to the built-in warning features of the T100, periodic inspection, regular zero/span checks, regular test parameter evaluation for predictive diagnostics and data analysis, and routine maintenance. Any instrument(s) supplying the zero air and span calibration gasses used must themselves be calibrated, and that calibration must be traceable to an EPA/NIST primary standard.

Comply with Code of Federal Regulations, Title 40 (downloadable from the U.S. Government Publishing Office at <http://www.gpo.gov/fdsys/>) and with Quality Assurance Guidance documents (available on the EPA website, <http://www.epa.gov/ttn/amtic/qalist.html>). Give special attention to specific regulations regarding the use and operation of ambient sulfur dioxide (fluorescence-based) analyzers.

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## 10. INSTRUMENT MAINTENANCE

Predictive diagnostic functions including data acquisition, failure warnings and alarms built into the analyzer allow the user to determine when repairs are necessary. However, preventive maintenance procedures that, when performed regularly, will help to ensure that the analyzer continues to operate accurately and reliably over its lifetime. Maintenance procedures are covered in this section, followed by troubleshooting and service procedures in Section 11 of this manual.

**Note:**

**To support your understanding of the technical details of maintenance, Section 12, *Principles of Operation*, provides information about how the instrument works.**

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

**A span and zero calibration check must be performed following some of the maintenance procedures listed below. Refer to Section 9.**



**WARNING! RISK OF ELECTRICAL SHOCK**

**Disconnect power before performing any operations that require entry into the interior of the analyzer, unless running the analyzer is necessary for a specific procedure.**



**All maintenance and service procedures must be performed only by a qualified technician.**

**Note**

**The front panel of the analyzer is hinged at the bottom and may be opened by two fasteners located in the upper right and left corners to gain access to various components that are either mounted on the panel itself or located near the front of the instrument (such as the particulate filter).**

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## 10.1. MAINTENANCE SCHEDULE

Table 10-1 is the recommended maintenance schedule for the T100. Please note that in certain environments with high levels of dust, humidity or pollutant levels some maintenance procedures may need to be performed more often than shown.

**Table 10-1: T100 Preventive Maintenance Schedule**

ITEM	ACTION	FREQUENCY	CAL CHECK	MANUAL SECTION	DATE PERFORMED					
<sup>1</sup> Particulate filter	Change particle filter	Weekly	No	10.3.1						
Verify test functions	Review and evaluate	Weekly	No	10.2; Appendix C						
Zero/span check	Evaluate offset and slope	Weekly	--	9.3, 9.6, 9.9						
<sup>1</sup> Zero/span calibration	Zero and span calibration	Every 3 months	--	9.2, 9.4, 9.5, 9.7, 9.8						
<sup>1</sup> External zero air scrubber (optional)	Exchange chemical	Every 3 months	No	10.3.3						
<sup>1</sup> Perform flow check	Check Flow	Every 6 Months	No	10.3.7						
Internal IZS Permeation Tube	Replace	Annually	YES	10.3.2						
Perform pneumatic leak check	Verify Leak Tight	Annually or after repairs involving pneumatics	Yes	10.3.6						
<sup>2</sup> Pump diaphragm	Replace	Annually	Yes	Refer to diaphragm kit instructions						
Calibrate UV Lamp Output	Perform <b>LAMP CAL</b>	Prior to zero/span calibration or PMT hardware calibration	--	5.9.6 & 11.7.2.5						
<sup>3</sup> PMT sensor hardware calibration	Low-level hardware calibration	On PMT/ preamp changes if $0.7 < \text{SLOPE}$ or $\text{SLOPE} > 1.3$	Yes	11.7.2.8						
<sup>1</sup> Sample chamber optics	Clean chamber, windows and filters	As necessary	Yes	11.7.2.2 & 11.7.2.3						
<sup>1</sup> Critical flow orifice & sintered filters	Replace	As necessary	Yes	10.3.4						

<sup>1</sup> These Items are required to maintain full warranty; all other items are strongly recommended.

<sup>2</sup> A pump rebuild kit is available from Teledyne API's Technical Support including all instructions and required parts (refer to Appendix B for part numbers).

<sup>3</sup> Replace desiccant bags each time the inspection plate for the sensor assembly is removed.

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## 10.2. PREDICTIVE DIAGNOSTICS

The analyzer's test functions can be used to predict failures by looking at trends in their values (refer to Table 10-2) and by comparing them values recorded for them at the factory and recorded on the *T100 Final Test and Validation Data Form* (Teledyne API P/N 04551) that was shipped with your analyzer.

A convenient way to record and track changes to these parameters is the internal data acquisition system (DAS) (see Section 7). Also, APICOM control software can be used to download and record these data for review even from remote locations (Section 7.3 discusses APICOM).

**Table 10-2: Predictive Uses for Test Functions**

TEST FUNCTION	DAS FUNCTION	CONDITION	BEHAVIOR		INTERPRETATION
			EXPECTED	ACTUAL	
PRES	SMPPRS	sample gas	Constant within atmospheric changes	Fluctuating	<ul style="list-style-type: none"> <li>Developing leak in pneumatic system</li> </ul>
				Slowly increasing	<ul style="list-style-type: none"> <li>Flow path is clogging up.               <ul style="list-style-type: none"> <li>- Check critical flow orifice &amp; sintered filter.</li> <li>- Replace particulate filter</li> </ul> </li> </ul>
				Slowly decreasing	<ul style="list-style-type: none"> <li>Developing leak in pneumatic system to vacuum (developing valve failure)</li> </ul>
DRK PMT	DRKPMT	PMT output when UV Lamp shutter closed	Constant within $\pm 20$ of check-out value	Significantly increasing	<ul style="list-style-type: none"> <li>PMT cooler failure</li> <li>Shutter Failure</li> </ul>
SO <sub>2</sub> Concentration	CONC1	At span with IZS option installed	Constant response from day to day	Decreasing over time	<ul style="list-style-type: none"> <li>Change in instrument response</li> <li>Degradation of IZS permeation tube</li> </ul>
		Standard configuration at span	stable for constant concentration	Decreasing over time	<ul style="list-style-type: none"> <li>Drift of instrument response; UV Lamp output is excessively low.</li> </ul>
SAMP FL	SMPFLW	Standard Operation	Stable	Slowly Decreasing	<ul style="list-style-type: none"> <li>Flow path is clogging up.               <ul style="list-style-type: none"> <li>- Check critical flow orifice &amp; sintered filter.</li> <li>- Replace particulate filter</li> </ul> </li> </ul>
				Fluctuating	<ul style="list-style-type: none"> <li>Leak in gas flow path.</li> </ul>
LAMP RATIO	LAMPR	Standard Operation	Stable and near 100%	Fluctuating or Slowly increasing	<ul style="list-style-type: none"> <li>UV detector wearing out</li> <li>UV source Filter developing pin holes</li> </ul>
				Slowly decreasing	<ul style="list-style-type: none"> <li>UV detector wearing out</li> <li>Opaque oxides building up on UV source Filter</li> <li>UV lamp aging</li> </ul>

## 10.3. MAINTENANCE PROCEDURES

The following procedures need to be performed regularly as part of the standard maintenance of the T100.

### 10.3.1. CHANGING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or excess dirt. It should be replaced according to the service interval in Table 10-1 even without obvious signs of dirt. Filters with 1 and 5  $\mu\text{m}$  pore size can clog up while retaining a clean look. We recommend handling the filter and the wetted surfaces of the filter housing with gloves and tweezers.

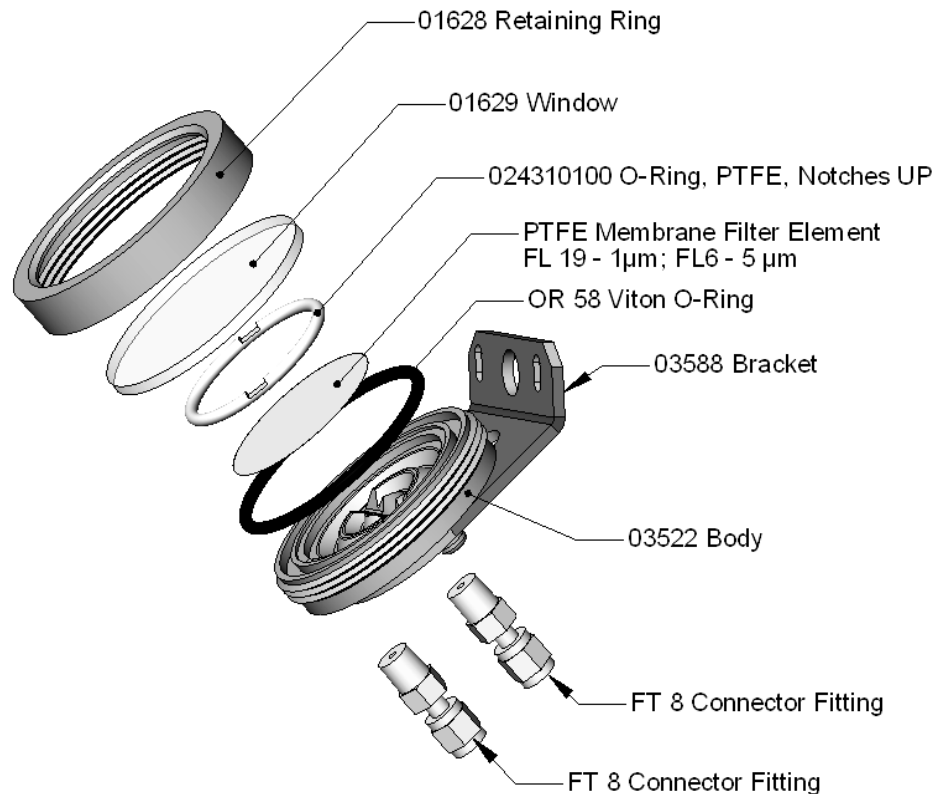
#### IMPORTANT

#### IMPACT ON READINGS OR DATA

**Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the O-ring with bare hands, as contamination can negatively impact accuracy of readings.**

To change the filter according to the service interval in Table 10-1:

1. Turn OFF the analyzer to prevent drawing debris into the sample line.
2. Open the analyzer's hinged front panel and unscrew the knurled retaining ring of the filter assembly.



**Figure 10-1: Sample Particulate Filter Assembly**

3. Carefully remove the retaining ring, glass window, PTFE O-ring and filter element.
4. Replace the filter element, carefully centering it in the bottom of the holder.
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.
6. Re-start the analyzer.

### 10.3.2. CHANGING THE IZS PERMEATION TUBE

1. Turn off the analyzer, unplug the power cord and remove the cover.
2. Locate the IZS oven in the rear left of the analyzer.
3. Remove the top layer of insulation if necessary.
4. Unscrew the black aluminum cover of the IZS oven (3 screws) using a medium Phillips-head screw driver. Leave the fittings and tubing connected to the cover.
5. Remove the old permeation tube if necessary and replace it with the new tube. Ensure that the tube is placed into the larger of two holes and that the open permeation end of the tube (Teflon) is facing up.
6. Re-attach the cover with three screws and ensure that the sealing O-ring is properly in place and that the three screws are tightened evenly.
7. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.
8. Carry out an IZS span check to see if the new permeation device works properly. The permeation rate may need several days to stabilize.

#### ATTENTION

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#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

**Do not leave instrument turned off for more than 8 hours without removing the permeation tube. Do not ship the instrument without removing the permeation tube. The tube continues to emit gas, even at room temperature and will contaminate the entire instrument.**

---

### 10.3.3. CHANGING THE EXTERNAL ZERO AIR SCRUBBER

The chemicals in the external scrubber need to be replaced periodically according to Table 10-1 or as needed. This procedure can be carried out while the instrument is running. Ensure that the analyzer is not in either the ZERO or SPAN calibration modes.

1. Locate the scrubber on the outside rear panel.
2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the particle filter using 9/16" and 1/2" wrenches.
3. Remove the particle filter from the cartridge using 9/16" wrenches.
4. Unscrew the top of the scrubber canister and discard charcoal contents. Ensure to abide by local laws for discarding these chemicals. The rebuild kit (listed in

Appendix B) comes with a Material and Safety Data Sheet, which contains more information on these chemicals.

5. Refill the scrubber with charcoal at the bottom.
6. Tighten the cap on the scrubber - hand-tight only.
7. Replace the DFU filter, if required, with a new unit and discard the old.
8. Replace the scrubber assembly into its clips on the rear panel.
9. Reconnect the plastic tubing to the fitting of the particle filter.
10. Adjust the scrubber cartridge such that it does not protrude above or below the analyzer in case the instrument is mounted in a rack. If necessary, squeeze the clips for a tighter grip on the cartridge.

#### 10.3.4. CHANGING THE CRITICAL FLOW ORIFICE

A critical flow orifice, located on the exhaust manifold maintains the proper flow rate of gas through the T100 analyzer. Refer to section 12.4.2.1 for a detailed description of its functionality and Section 12.4.1 for its location. Despite the fact this device is protected by sintered stainless steel filters, it can, on occasion, clog, particularly if the instrument is operated without a sample filter or in an environment with very fine, sub-micron particle-size dust.

1. Turn off power to the instrument and vacuum pump.
2. Locate the critical flow orifice on the pressure sensor assembly (called out in Figure 10-2).
3. Disconnect the pneumatic line.
4. Unscrew the NPT fitting.

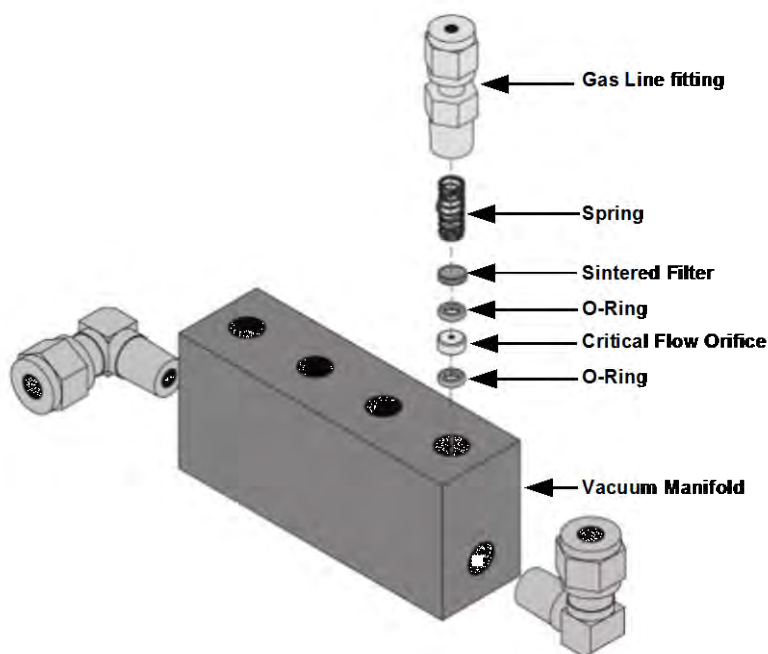


Figure 10-2: Critical Flow Orifice Assembly

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.
6. Discard the two O-rings and the sintered filter.
7. Replace the critical flow orifice.
8. Let the part dry.
9. Re-assemble the parts as shown in Figure 10-2 using a new filter and o-rings.
10. Reinstall the NPT fitting and connect all tubing.
11. Power up the analyzer and allow it to warm up for 60 minutes.
12. Perform a leak check (refer to Section 10.3.6).

### 10.3.5. CHECKING FOR LIGHT LEAKS

When re-assembled after maintenance, repair or improper operation, the T100 can develop small leaks around the PMT, allowing stray light from the analyzer surroundings into the PMT housing. To find light leaks, follow the below procedures:

#### CAUTION



**This procedure must be carried out by qualified personnel, as it must be performed while the analyzer is powered up and running and its cover removed.**

#### WARNING RISK OF ELECTRICAL SHOCK



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

1. Scroll the TEST functions to PMT.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover. Take extra care not to touch any of the inside wiring with the metal cover or your body. Do not drop screws or tools into a running analyzer!
4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the sample chamber as well as around the PMT housing. The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise performance.

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.
6. Carefully replace the analyzer cover.
7. If tubing was changed, carry out a leak check (refer to Section 10.3.6).

### 10.3.6. DETAILED PRESSURE LEAK CHECK

Obtain a leak checker that 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  $\leq 15$  psi, a shutoff valve and pressure gauge may be used.

#### ATTENTION

---

#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

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

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

---

1. Turn OFF power to the instrument and remove the instrument cover.
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.
3. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.
4. Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.
5. 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.
6. Do not exceed 15 psi pressure.
7. 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.
8. 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. 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.
10. Clean soap solution from all surfaces, re-connect the sample and exhaust lines and replace the instrument cover. Restart the analyzer.



### 10.3.7. PERFORMING A SAMPLE FLOW CHECK

#### IMPORTANT

#### IMPACT ON READINGS OR DATA

**Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm<sup>3</sup>/min to measure the gas flow rate through the analyzer. For this procedure, do not refer to the built in flow measurement shown in the front panel display screen.**

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:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port (Figure 3-4).
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.
3. The sample flow measured with the external flow meter should be 650 cm<sup>3</sup>/min  $\pm$  10%.
4. Low flows indicate blockage somewhere in the pneumatic pathway. Refer to troubleshooting Section 11.3 for more information on how to fix this.

### 10.3.8. HYDROCARBON SCRUBBER (*KICKER*)

There are two possible types of problems that can occur with the scrubber: pneumatic leaks and contamination that ruins the inner tube's ability to absorb hydrocarbons.

#### 10.3.8.1. CHECKING THE SCRUBBER FOR LEAKS

Leaks in the outer tubing of the scrubber can be found using the procedure described in Section 10.3.6. Use the following method to determine if a leak exists in the inner tubing of the scrubber.

This procedure requires a pressurized source of air (chemical composition is unimportant) capable of supplying up to 15 psiA and a leak checking fixture such as the one illustrated in Figure 10-3.

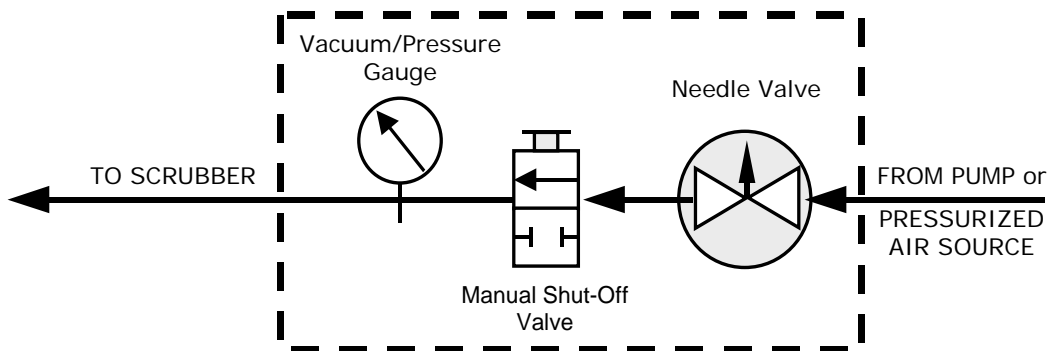
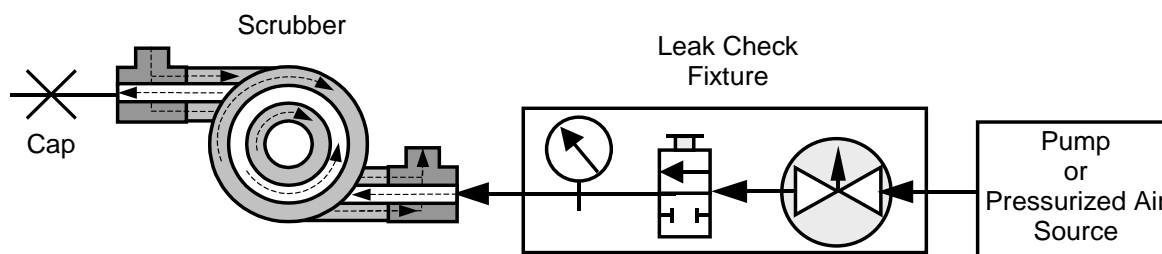


Figure 10-3: Simple Leak Check Fixture

1. Turn off the analyzer.
2. Disconnect the pneumatic tubing attached to both ends of the scrubber's inner tubing.
3. One end is connected to the sample particulate filter assembly and the other end is connected to the reaction cell assembly.
4. Both ends are made of the 1/8" black Teflon tubing.
5. Cap one end of the hydrocarbon scrubber.
6. Attach the pressurized air source to the other end of the scrubber inner tubing with the leak check fixture in line.



**Figure 10-4: Hydrocarbon Scrubber Leak Check Setup**

7. Use the needle valve to adjust the air input until the gauge reads 15 psiA.

## ATTENTION

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**  
**Do not exceed a pressure of more than 15 psia.**  
**Do not pull the vacuum through the scrubber.**  
 -----

8. Close the shut-off valve.
9. Wait 5 minutes.

If the gauge pressure drops >1 psi within 5 minutes, then the hydrocarbon scrubber has an internal leak and must be replaced. Contact Teledyne API's Technical Support.

# 11. TROUBLESHOOTING & SERVICE

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

**Note:**

To support your understanding of the technical details of maintenance, Section 12, *Principles of Operation*, provides information about how the instrument works.



**CAUTION**

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



**WARNING  
RISK OF ELECTRICAL SHOCK**

SOME OPERATIONS NEED TO BE CARRIED OUT WITH THE ANALYZER OPEN AND RUNNING. EXERCISE CAUTION TO AVOID ELECTRICAL SHOCKS AND ELECTROSTATIC OR MECHANICAL DAMAGE TO THE ANALYZER. DO NOT DROP TOOLS INTO THE ANALYZER OR LEAVE THOSE AFTER YOUR PROCEDURES. DO NOT SHORTEN OR TOUCH ELECTRIC CONNECTIONS WITH METALLIC TOOLS WHILE OPERATING INSIDE THE ANALYZER. USE COMMON SENSE WHEN OPERATING INSIDE A RUNNING ANALYZER.

**Note**

The front panel of the analyzer is hinged at the bottom and may be opened to gain access to various components mounted on the panel itself or located near the front of the instrument (such as the particulate filter).

Remove the locking screw located at the right-hand side of the front panel.

## 11.1. GENERAL TROUBLESHOOTING

The T100 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 key 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 analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.
4. Suspect a leak first!
  - Technical Support data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.
  - Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged / malfunctioning pumps, etc.
5. Follow the procedures defined in Section 11.6 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touch-screen display, PMT cooler, etc.).
  - Refer to Figure 3-5 for the general layout of components and sub-assemblies in the analyzer.
  - Refer to the wiring interconnect diagram and interconnect list in Appendix D.

### 11.1.1. FAULT DIAGNOSTICS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message displayed on the front panel. Table 11-1 contains a list of warning messages, along with their meaning and recommended corrective action.

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

The analyzer will alert the user that a Warning message is active by flashing the 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:



The analyzer also issues a message via the serial port(s).

To view or clear a warning message press:

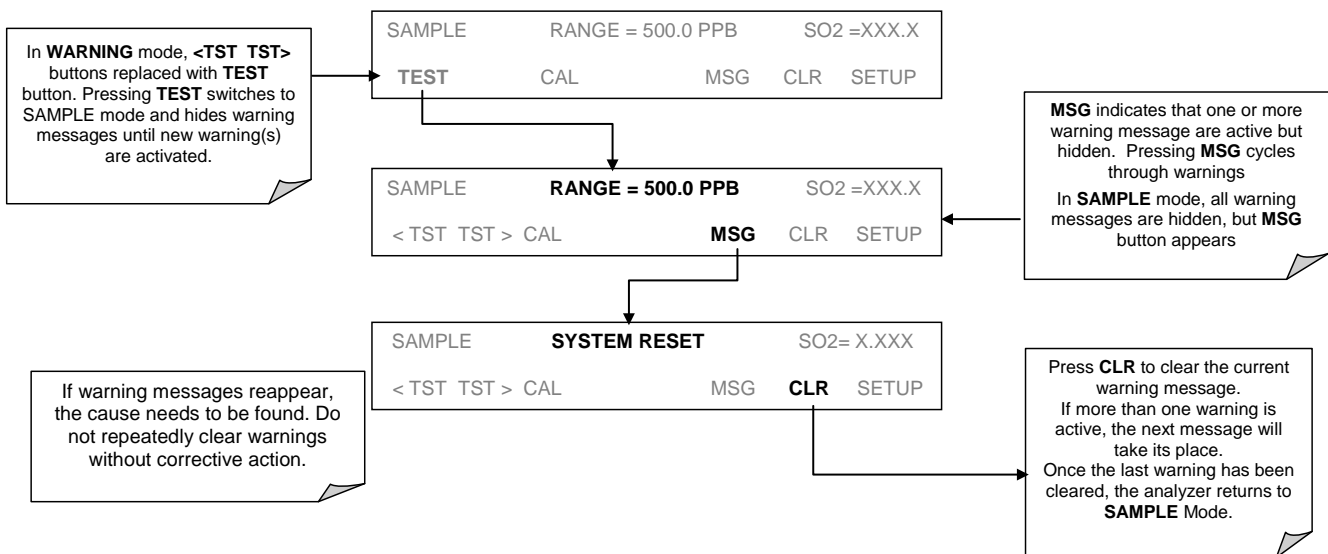


Figure 11-1: Viewing and Clearing Warning Messages

Table 11-1: Warning Messages - Indicated Failures

Warning Message	Fault Condition	Possible Causes
<b>ANALOG CAL WARNING</b>	The instruments A/D circuitry or one of its analog outputs is not calibrated	A parameter for one of the analog outputs, even one not currently being used, has been changed and the analog output calibration routine was not re-run A/D circuitry failure on motherboard Other motherboard electronic failure
<b>BOX TEMP WARNING</b>	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
<b>CANNOT DYN SPAN</b>	Dynamic Span operation failed	Measured concentration value is too high or low. Concentration slope value too high or too low
<b>CANNOT DYN ZERO</b>	Dynamic Zero operation failed	Measured concentration value is too high. Concentration offset value too high.
<b>CONFIG INITIALIZED</b>	Configuration and Calibration data reset to original Factory state.	Failed disk on module User erased data
<b>DARK CAL WARNING</b>	The Dark Cal signal is higher than 200 mV.	Light leak in reaction cell Shutter solenoid is not functioning Failed relay board I <sup>2</sup> C bus failure Loose connector/wiring PMT preamp board bad or out of cal
<b>DATA INITIALIZED</b>	Data Storage in DAS was erased	Failed disk on module User cleared data
<b>HVPS WARNING</b>	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
<b>IZS TEMP WARNING</b>	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 <sup>2</sup> C bus malfunction Failure of thermistor interface circuitry on motherboard
<b>PMT DET WARNING</b>	PMT detector output is > 4995 mV	Failed PMT Malfunctioning PMR preamp board A/D converter circuitry failure
<b>PMT TEMP WARNING</b>	PMT 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
<b>RCELL TEMP WARNING</b>	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 <sup>2</sup> C bus malfunction
<b>REAR BOARD NOT DET</b>	Mother Board not detected on power up.	Warning only appears on serial I/O COMM port(s) Front panel display will be frozen, blank or will not respond. Massive failure of mother board.
<b>SAMPLE FLOW WARN</b>	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
<b>SAMPLE PRES WARN</b>	Sample Pressure is <10 in-Hg or > 35 in-Hg <sup>1</sup>	If sample pressure is < 10 in-hg: <ul style="list-style-type: none"> <li>o Blocked particulate filter</li> <li>o Blocked sample inlet/gas line</li> <li>o Failed pressure sensor/circuitry</li> </ul> If sample pressure is > 35 in-hg: <ul style="list-style-type: none"> <li>o Blocked vent line on pressurized sample/zero/span gas supply</li> <li>o Bad pressure sensor/circuitry</li> </ul>

Warning Message	Fault Condition	Possible Causes
<b>SAMPLE PRES WARN</b>	Sample Pressure is <10 in-Hg or > 35 in-Hg <sup>1</sup>	If sample pressure is < 10 in-hg: <ul style="list-style-type: none"> <li>o Blocked particulate filter</li> <li>o Blocked sample inlet/gas line</li> <li>o Failed pressure sensor/circuitry</li> </ul> If sample pressure is > 35 in-hg: <ul style="list-style-type: none"> <li>o Blocked vent line on pressurized sample/zero/span gas supply</li> <li>o Bad pressure sensor/circuitry</li> </ul>
<b>SYSTEM RESET</b>	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
<b>UV LAMP WARNING</b>	The UV lamp intensity is < 600mV or > 4995 mV	UV lamp is bad Reference detector is bad or out of adjustment. Mother board analog sensor input circuitry has failed. Fogged or damaged lenses/filters in UV light path A/D converter circuitry failure Light leak in reaction cell Shutter solenoid stuck closed
<sup>1</sup> Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).		

**IMPORTANT****IMPACT ON READINGS OR DATA**

**A failure of the analyzer's CPU, motherboard or power supplies can result in any or ALL of the above messages.**

**11.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS**

Besides being useful as predictive diagnostic tools, the TEST functions, viewable from the front panel, can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer's principles of operation (refer to Section 12. We recommend use of the APICOM remote control program (Section 7) to download, graph and archive TEST data for analysis, and long-term monitoring of diagnostic data.

The acceptable ranges for these test functions are listed in Table A-3 in Appendix A-3. The actual values for these test functions on checkout at the factory were also listed in the *Final Test and Validation Data Sheet*, which was shipped with the instrument. Values outside the acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions with values that are within the acceptable range but have significantly changed from the measurements recorded on the factory data sheet may also indicate a failure or a maintenance item.

A problem report worksheet has been provided in Appendix C to assist in recording the value of these test functions. Table 11-2 contains some of the more common causes for these values to be out of range.

**IMPORTANT****IMPACT ON READINGS OR DATA**

**A value of "XXXX" displayed for any of these TEST functions indicates an OUT OF RANGE reading.**

Note

Sample Pressure measurements are represented in terms of absolute pressure because this is the least ambiguous method reporting gas pressure. Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 1000 ft gain in altitude. A variety of factors such as air conditioning systems, passing storms, and air temperature, can also cause changes in the absolute atmospheric pressure.

Table 11-2: Test Functions - Possible Causes for Out-Of-Range Values

TEST FUNCTION	NOMINAL VALUE(S)	POSSIBLE CAUSE(S)
STABIL	≤1 ppb with Zero Air	Faults that cause high stability values are: pneumatic leak; low or very unstable UV lamp output; light leak; faulty HVPS; defective preamp board; aging detectors; PMT recently exposed to room light; dirty/contaminated reaction cell.
SAMPLE FL	650 cm <sup>3</sup> /min ± 10%	Faults are caused due to: clogged critical flow orifice; pneumatic leak; faulty flow sensor; sample line flow restriction.
PMT	-20 TO 150 mV with Zero Air	High or noisy readings could be due to: calibration error; pneumatic leak; excessive background light; aging UV filter; low UV lamp output; PMT recently exposed to room light; light leak in reaction cell; reaction cell contaminated HVPS problem. <i>It takes 24-48 hours for the PMT exposed to ambient light levels to adapt to dim light.</i>
NORM PMT	0-5000 mV, 0-20,000 ppb @ Span Gas Concentration	Noisy Norm PMT value (assuming unchanging SO <sub>2</sub> concentration of sample gas): Calibration error; HVPS problem; PMT problem.
UV LAMP SIGNAL	2000 - 4000 mV	This is the instantaneous reading of the UV lamp intensity. Low UV lamp intensity could be due to: aging UV lamp; UV lamp position out of alignment; faulty lamp transformer; aging or faulty UV detector; UV detector needs adjusting; dirty optical components. Intensity lower than 600 mV will cause <b>UV LAMP WARNING</b> . Most likely cause is a UV lamp in need of replacement.
LAMP RATIO	30 TO 120%	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 performed. Out of range lamp ratio could be due to: malfunctioning UV lamp; UV lamp position out of alignment; faulty lamp transformer; aging or faulty UV detector; dirty optical components; pin holes or scratches in the UV optical filters; light leaks.
STR LGT	≤ 100 ppb / Zero Air	High stray light could be caused by: aging UV filter; contaminated reaction cell; light leak; pneumatic leak.
DRK PMT	-50 to +200 mV	High dark PMT reading could be due to: light leak; shutter not closing completely; high pmt temperature; high electronic offset.
DRK LMP	-50 to +200 mV	High dark UV detector could be caused by: light leak; shutter not closing completely; high electronic offset.
HVPS	≈ 400 V to 900 V	Incorrect HVPS reading could be caused by: HVPS broken; preamp board circuit problems.
RCELL TEMP	50°C ± 1°C	Incorrect temperature reading could be caused by: malfunctioning heater; relay board communication (I <sup>2</sup> C bus); relay burnt out
BOX TEMP	Ambient + ≈ 5°C	Incorrect temperature reading could be caused by: Environment out of temperature operating range; broken thermistor; runaway heater
PMT TEMP	7°C ± 2°C Constant	Incorrect temperature reading could be caused by: TEC cooling circuit broken; High chassis temperature; 12V power supply
IZS TEMP (option)	50°C ± 1°C	Malfunctioning heater; relay board communication (I <sup>2</sup> C bus); relay burnt out
PRESS	Ambient ± 2 IN-HG-A	Incorrect sample gas pressure could be due to: pneumatic leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure; faulty pressure sensor
SLOPE	1.0 ± 0.3	Slope out of range could be due to: poor calibration quality; span gas concentration incorrect; leaks; UV Lamp output decay.
OFFSET	< 250 mV	High offset could be due to: incorrect span gas concentration/contaminated zero air/leak; low-level calibration off; light leak; aging UV filter; contaminated reaction cell; pneumatic leak.
TIME OF DAY	Current Time	Incorrect Time could be caused by: Internal clock drifting; move across time zones; daylight savings time?



### 11.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTIONS

The signal I/O parameters found under the diagnostics (DIAG) menu combined with a thorough understanding of the instrument's principles of operation (refer to Section 12) are useful for troubleshooting in three ways:

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

This allows a user to systematically observe the effect of these functions on the operation of the analyzer. Figure 11-2 shows an example of how to use the signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal. The specific parameter will vary depending on the situation. Please note that the analyzer will freeze its concentration output while in the diagnostic signal I/O menu. This is because manually changing I/O outputs can invalidate the instrument reading.

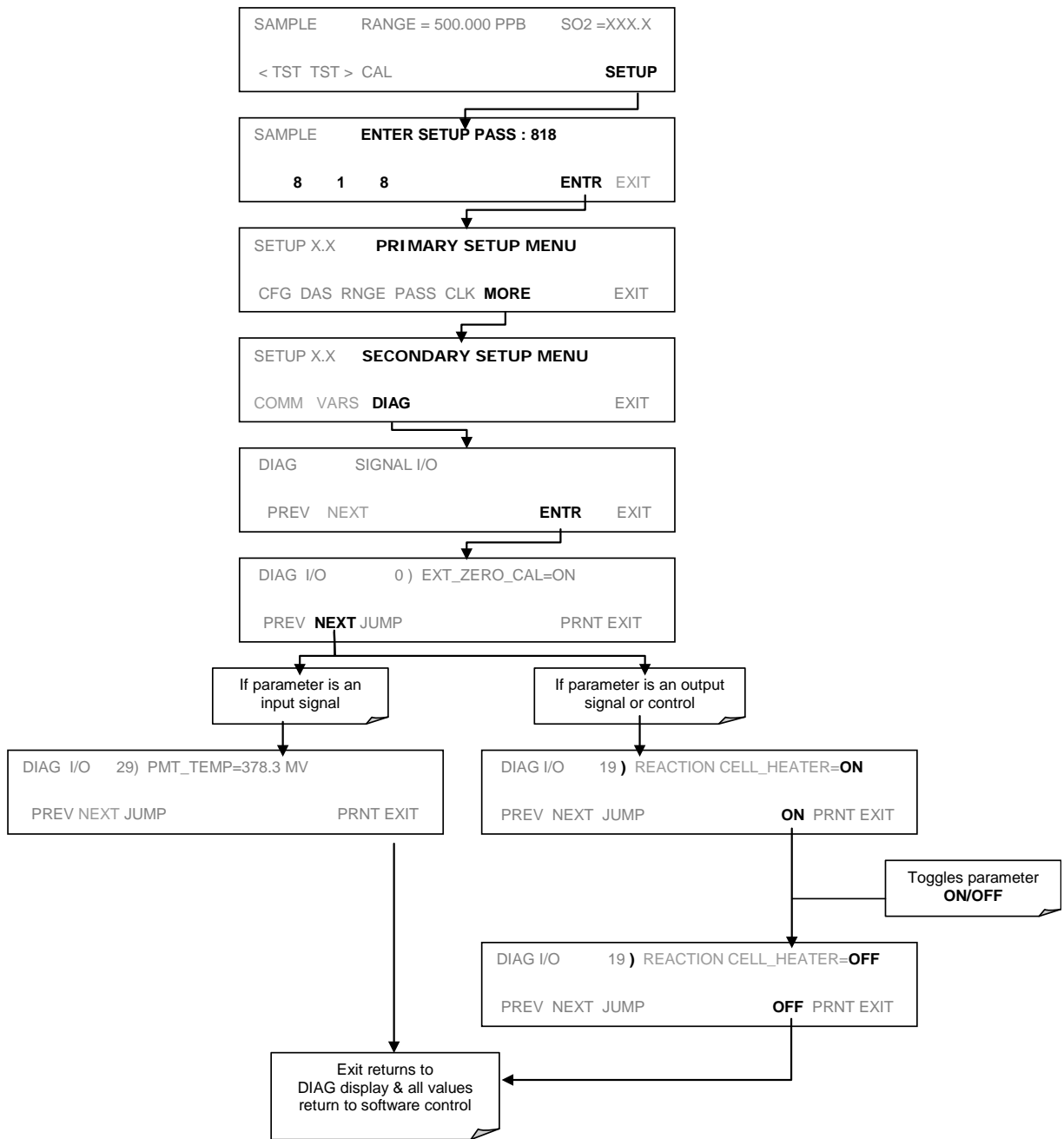


Figure 11-2: Example of Signal I/O Function

## 11.2. STATUS LEDS

Several color-coded, light-emitting diodes (LEDs) are located inside the instrument to determine if the analyzer's CPU, I<sup>2</sup>C communications bus and relay board are functioning properly.

### 11.2.1. MOTHERBOARD STATUS INDICATOR (WATCHDOG)

DS5, a red LED on the upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program. After power-up, DS5 should flash on and off about once per second. If characters are written to the front panel display but DS5 does not flash then the program files have become corrupted. Contact Teledyne API's Technical Support department.

If DS5 is not flashing 30 - 60 seconds after a restart and no characters have been written to the front panel display, the firmware may be corrupted or the CPU may be defective. If DS5 is permanently off or permanently on, the CPU board is likely locked up and should the analyzer not respond (either with locked-up or dark front panel), then replace the CPU.

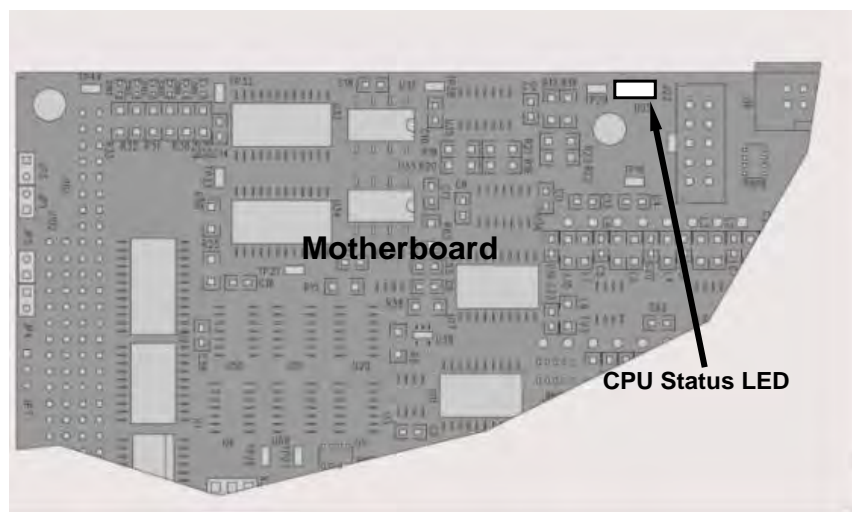


Figure 11-3: CPU Status Indicator

### 11.2.2. CPU STATUS INDICATORS

The LEDs on the CPU card (Figure 12-14) are described as follows:

Power LED	Red	normally lit
IDE LED	Green	lit when active (read or write)

### 11.2.3. RELAY BOARD STATUS LEDS

The most important status LED on the relay board is the red I<sup>2</sup>C Bus watch-dog LED, labeled **D1** (or W/D), which indicates the health of the I<sup>2</sup>C communications bus. This LED is located in the upper left-hand corner of the relay board when looking at the electronic components. If D1 is blinking, then the other LEDs can be used in conjunction with the **DIAG** menu I/O functions to test hardware functionality by switching devices on and off and watching the corresponding LED turn on or off. The LED only indicates that the logic signal for an output has been activated. If the output driver (i.e. the relay or valve driver IC) is defective, then the LED will light up, but the attached peripheral device will not turn on.

**Table 11-3: Relay Board Status LEDs**

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
D1	red	Watchdog Circuit; I <sup>2</sup> C bus operation.	Continuously ON or OFF	Failed/Halted CPU Faulty Mother Board, Valve Driver board or Relay PCA Faulty Connectors/Wiring between Motherboard, Valve Driver board or Relay PCA Failed/Faulty +5 VDC Power Supply (PS1)

### 11.3. GAS FLOW PROBLEMS

The standard analyzer has one main flow path. With the IZS option installed, there is a second flow path through the IZS oven that runs whenever the IZS is on standby to purge SO<sub>2</sub> from the oven chamber. The IZS flow is not measured so there is no reading for it on the front panel display. The full flow diagrams of the standard configuration (refer to Figure 3-18) and with options installed (refer to Figure 3-19 and Figure 3-21) help in troubleshooting flow problems. In general, flow problems can be divided into three categories:

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

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer’s flow display. The use of an independent, external flow meter to perform a flow check as described in Section 11.5.2 is essential.

#### 11.3.1. ZERO OR LOW SAMPLE FLOW

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

- Check for actual sample flow
- Check pressures
- Carry out a leak check

To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument. Ensure 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 a proper flow of approximately 650 cm<sup>3</sup>/min exists, contact Technical Support. If there is no flow or low flow, continue with the next step.

Check that the sample pressure is at or around 28 (or about 1 in-Hg-A below ambient atmospheric pressure).

### 11.3.2. HIGH FLOW

Flows that are significantly higher than the allowed operating range (typically  $\pm 10$ -11% of the nominal flow) should not occur in the M 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.

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

## 11.4. CALIBRATION PROBLEMS

This section provides information regarding possible causes of various calibration problems.

### 11.4.1. NEGATIVE CONCENTRATIONS

Negative concentration values may be caused due to the following:

- 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 -5 ppb, but should alternate with similarly high, positive values.
- Mis-calibration is the most likely explanation for negative concentration values. If the zero air contained some SO<sub>2</sub> 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 SO<sub>2</sub>. The same problem occurs, if the analyzer was zero-calibrated using ambient air or span gas.
- If the response offset test function for SO<sub>2</sub> (**OFFSET**) are greater than 150 mV, a failed PMT or high voltage supply, or sample chamber contamination, could be the cause.

### 11.4.2. 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,

- Confirm response by supplying SO<sub>2</sub> span gas of about 80% of the range value to the analyzer.
- Check the sample flow rate for proper value.

- Check for disconnected cables to the sensor module.
- Carry out an electrical test with the **ELECTRICAL TEST** (EATEST) procedure in the diagnostics menu, refer to Section 5.9.5. If this test produces a concentration reading, the analyzer's electronic signal path is working.
- Carry out an optical test using the **OPTIC TEST** (OATEST) procedure in the diagnostics menu, refer to Section 5.9.4. If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly. If it passes both EATEST and OATEST, 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.

### 11.4.3. UNSTABLE ZERO AND SPAN

Leaks in the T100 or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

- Check for leaks in the pneumatic systems as described in Section 10.3.6. Consider pneumatic components in the gas delivery system outside the T100 such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.
- Once the instrument passes a leak check, perform a flow check (refer to Section 10.3.7) to ensure that the instrument is supplied with adequate sample gas.
- Confirm the UV lamp, sample pressure and sample temperature readings are correct and steady.
- Verify that the sample filter element is clean and does not need to be replaced.

### 11.4.4. INABILITY TO SPAN - NO SPAN BUTTON

In general, the T100 will not display certain control buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a 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.

- Verify that the expected concentration is set properly to the actual span gas concentration in the **CONC** sub-menu.
- Confirm that the SO<sub>2</sub> span gas source is accurate.
- If you are using bottle calibration gas and have recently changed bottles, bottle to bottle variation may be the cause.
- Check for leaks in the pneumatic systems as described in Section 11.6.1. Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the **CONC** sub-menu.
- If the 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). Refer to Section 11.7.2.8 on how to carry out a low-level hardware calibration.

### 11.4.5. INABILITY TO ZERO - NO ZERO BUTTON

In general, the T100 will not display certain control buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a ZERO button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

- Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to an external zero air source using SO<sub>2</sub>-free air. Check any zero air scrubber for performance and replacement (refer to Section 10.3.3).
- Check to ensure that there is no ambient air leaking into the zero air line. Check for leaks in the pneumatic systems as described in Section 10.3.6.

### 11.4.6. NON-LINEAR RESPONSE

The T100 was factory calibrated and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system. Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed. Check for leaks as described in Section 11.6.
- The calibration device is in error. Check flow rates and concentrations, particularly when using low concentrations. If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.
- The standard gases may be mislabeled as to type or concentration. Labeled concentrations may be outside the certified tolerance.
- The sample delivery system may be contaminated. Check for dirt in the sample lines or sample chamber.
- Calibration gas source may be contaminated.
- Dilution air contains sample or span gas.
- Sample inlet may be contaminated with SO<sub>2</sub> exhaust from this or other analyzers. Verify proper venting of the analyzer's exhaust.
- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port. Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line. Ensure to create and properly vent excess span gas.
- If the instrument is equipped with an internal IZS valve option and the SO<sub>2</sub> span value is continuously trending downward, the IZS permeation tube may require replacement.

### 11.4.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree with the value reported on the front panel, you may need to re-calibrate the analog outputs. This becomes more likely when using a low concentration or low analog output range. Analog outputs running at 0.1 V full scale should always be calibrated manually. Refer to Section 5.9.3.3 for a detailed description of this procedure.

## 11.5. 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.

### 11.5.1. EXCESSIVE NOISE

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

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

### 11.5.2. SLOW RESPONSE

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

- Dirty or plugged sample filter or sample lines.
- Sample inlet line is too long.
- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (refer to Section 10.3.4).
- Wrong materials in contact with sample - use Teflon materials only.
- Sample vent line is located too far from the instrument sample inlet causing a long mixing and purge time. Locate sample inlet (overflow) vent as close as possible to the analyzer's sample inlet port.
- Dirty sample chamber.
- Insufficient time allowed for purging of lines upstream of the analyzer.
- Insufficient time allowed for SO<sub>2</sub> calibration gas source to become stable.

### 11.5.3. THE ANALYZER 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 analyzer (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.

## 11.6. 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.

### 11.6.1. AC POWER CONFIGURATION

The T100 digital electronic systems will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display. Internally, the status LEDs located on the Motherboard, the Relay PCA and the CPU should turn on as soon as the power is supplied.

On the other hand, the analyzer's various non-digital components, such as the pump and the AC powered heaters, require that the relay board be properly configured for the type of power being supplied to the instrument.

#### ATTENTION

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#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

**Plugging the analyzer into a power supply that is too high a voltage or frequency can damage the pump and the AC Heaters.**

**Plugging the analyzer into a power supply that is too low a voltage or frequency will cause these components to not operate properly.**

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If the pump and the heaters are not working correctly and incorrect power configuration is suspected, check the serial number label located on the instrument's rear panel (refer to Figure 3-4) to ensure that the instrument was configured for the same voltage and frequency being supplied.

If the information included on the label matches the line voltage, but you still suspect an AC power configuration problem:

For the heaters, check the power configuration jumpers located on the relay board (refer to Figure 11-4).

- If the Jumper block is WHITE the heaters are configured for 115 VAC at 60 Hz.
- If the Jumper block is BLUE the heaters are configured for 220, 240 VAC at 50 Hz.

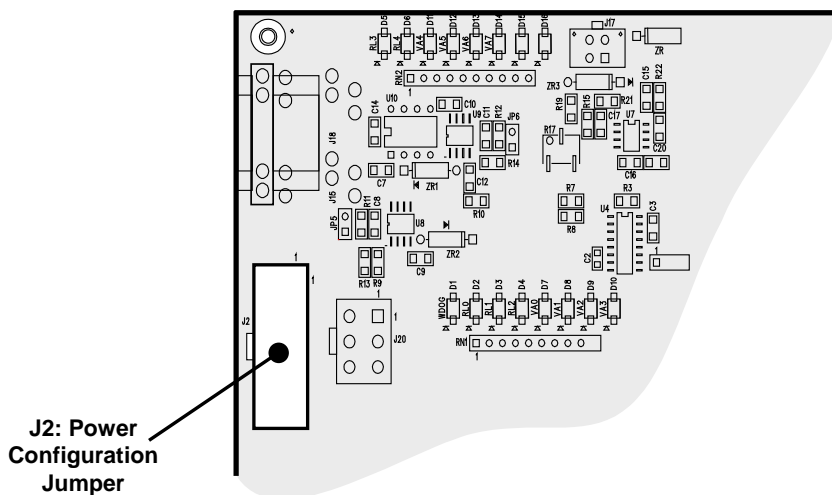


Figure 11-4: Location of Relay Board Power Configuration Jumper

AC Configuration of the pump is accomplished via an in-line, hard wired, set of connections. Call Teledyne API’s Technical Support Department for more information.

### 11.6.2. DC POWeR SUPPLY

If you have determined that the analyzer’s AC main 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, which convert AC power to 5 and ±15 V (PS1) as well as +12 V DC power (PS2). The supplies can either have DC output at all or a noisy output (fluctuating).

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 board follow a standard color-coding scheme as defined in Table 11-4.

Table 11-4: DC Power Test Point and Wiring Color Code

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12V	6	Purple	
+12R	7	Orange	12 V return (ground) line

A voltmeter should be used to verify that the DC voltages are correct as listed in Table 11-4. An oscilloscope, in AC mode and with band limiting turned on, can be used to evaluate if the supplies are excessively noisy (>100 mV peak-to-peak).

Table 11-5: DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM TEST POINT		TO TEST POINT			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.80	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0
PS1	-15	AGND	3	-15V	5	-14.0	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.8	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.05	+0.05

### 11.6.3. I<sup>2</sup>C BUS

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

### 11.6.4. TOUCH-SCREEN INTERFACE

Verify the functioning of the touch screen by observing the display when pressing a touch-screen control button. Assuming that there are no wiring problems and that the DC power supplies are operating properly, but pressing a control button on the touch screen does not change the display, any of the following may be the problem:

- The touch-screen controller may be malfunctioning.
- The internal USB bus may be malfunctioning.

You can verify this failure by logging on to the instrument using APICOM or a terminal program. If the analyzer responds to remote commands and the display changes accordingly, the touch-screen interface may be faulty.

### 11.6.5. 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.

### 11.6.6. RELAY BOARD

The relay board circuit can most easily be checked by observing the condition of its status LEDs as described in Section 11.2, and the associated output when toggled on and off through the **SIGNAL I/O** function in the **DIAG** menu, refer to Section 5.9.1.

- If the front panel display responds to button presses and D1 on the relay board is not flashing, then either the I<sup>2</sup>C connection between the motherboard and the relay board is bad, or the relay board itself is bad.
- If D1 on the relay board is flashing, but toggling an output in the **Signal I/O** function menu does not toggle the output's status LED, then there is a circuit problem, or possibly a blown driver chip, on the relay board.
- If D1 on the Relay board is flashing and the status indicator for the output in question (heater, valve, etc.) toggles properly using the **Signal I/O** function, but the output device does not turn on/off, then the associated device (valve or heater) or its control device (valve driver, heater relay) is malfunctioning.

Several of the control devices are in sockets and can easily be replaced. The table below lists the control device associated with a particular function:

**Table 11-6: Relay Board Control Devices**

FUNCTION	CONTROL DEVICE	SOCKETED
Valve0 – Valve3	U5	Yes
Valve4 – Valve7	U6	Yes
All heaters	K1-K5	Yes

### 11.6.7. MOTHERBOARD

#### 11.6.7.1. A/D FUNCTIONS

A basic check of the analog to digital (A/D) converter operation on the motherboard is to use the **Signal I/O** function under the **DIAG** menu. Check the following two A/D reference voltages and input signals that can be easily measured with a voltmeter. Using the **Signal I/O** function (refer to Section 5.9.1 and Appendix D), view the value of **REF\_4096\_MV** and **REF\_GND**.

- The nominal value for **REF\_4096\_MV** is 4096 mV ± 10 mV.
- The nominal value for **REF\_GND** is 0 mV ± 3 mV, respectively, of their nominal values (4096 and 0) and are
- If these signals are stable to within ±0.5 mV, the basic A/D converter is functioning properly.
- If these values fluctuate largely or are off by more than specified above, one or more of the analog circuits may be overloaded or the motherboard may be faulty.
- Choose one parameter in the Signal I/O function such as **SAMPLE\_PRESSURE** (refer to previous section on how to measure it). Compare its actual voltage with the voltage displayed through the **SIGNAL I/O** function. If the wiring is intact but there is a difference of more than ±10 mV between the measured and displayed voltage, the motherboard may be faulty.

### 11.6.7.2. ANALOG OUTPUT VOLTAGES

To verify that the analog outputs are working properly, connect a voltmeter to the output in question and perform an analog output step test as described in Section 5.9.2.

For each of the steps, taking into account any offset that may have been programmed into the channel (refer to Section 5.9.3.4), the output should be within 1% of the nominal value listed in the Table 11-7 except for the 0% step, which should be within 2-3 mV. If one or more of the steps is outside of this range, a failure of one or both D/A converters and their associated circuitry on the motherboard is likely.

**Table 11-7: Analog Output Test Function - Nominal Values**

		FULL SCALE OUTPUT VOLTAGE			
		100MV	1V	5V	10V*
STEP	%	NOMINAL OUTPUT VOLTAGE			
1	0	0 mV	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10

\* Increase the Analog Out (AOUT) Cal Limits in the DIAG>Analog I/O Config menu.

### 11.6.7.3. STATUS OUTPUTS

The procedure below can be used to test the Status outputs.

1. Connect a cable jumper between the “-“ pin and the “▽” pin on the status output connector.
2. Connect a 1000 Ω resistor between the +5 V and the pin for the status output that is being tested.

**Table 11-8: Status Outputs Check Pin Out**

PIN (left to right)	STATUS
1	System Ok
2	Conc Valid
3	High Range
4	Zero Cal
5	Span Cal
6	Diag Mode
7	Spare
8	Spare

3. Connect a voltmeter between the “-“ pin and the pin of the output being tested (refer to Table 11-8).
4. Under the **DIAG → SIGNAL I/O** menu (refer to Section 5.9.1), scroll through the inputs and outputs until you get to the output in question. 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.

#### 11.6.7.4. CONTROL INPUTS

The control input bits can be tested by the following procedure:

1. Connect a jumper from the +5 V pin on the STATUS connector to the U on the CONTROL IN connector.
2. Connect a second jumper from the  $\nabla$  pin on the STATUS connector to the A pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **ZERO CAL R** mode.
3. Connect a second jumper from the  $\nabla$  pin on the STATUS connector to the B pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **SPAN CAL R** mode.

In each case, the T100 should return to SAMPLE mode when the jumper is removed.

#### 11.6.8. 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.

#### 11.6.9. RS-232 COMMUNICATION

This section provides general RS-232 communication information.

##### 11.6.9.1. GENERAL RS-232 TROUBLESHOOTING

Teledyne API's analyzers use the RS-232 protocol as the standard, serial communications protocol. RS-232 is a versatile standard, which has been used for many years but, at times, is difficult to configure. Teledyne API conforms to the standard pin assignments in the implementation of RS-232. Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. This is the most common problem. Refer to Section 3.3.1.8 for connector, pin-out and setup information.
- The communications (baud) rate and protocol parameters are incorrectly configured. Refer to 3.3.1.8 and 6.2 for baud rate information.
- The COMM port communications mode is set incorrectly (refer to Section 6.2.1).
- If a modem is used, additional configuration and wiring rules must be observed. Refer to Section 8.3.
- Incorrect setting of the DTE - DCE Switch. Refer to Section 6.1.

### 11.6.9.2. MODEM OR TERMINAL OPERATION

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

- Check cables for proper connection to the modem, terminal or computer.
- Check the correct position of the DTE/DCE switch as described in Section 6.1.
- Check the correct setup command (refer to Section 8.3).
- Verify that the Ready to Send (RTS) signal is at logic high. The T100 sets Pin 7 (RTS) to greater than 3 volts to enable modem transmission.
- Ensure that the baud rate, word length, and stop bit settings between modem and analyzer match (refer to Sections 6.2.2 and 8.3).
- Use the RS-232 test function to send “w” characters to the modem, terminal or computer. Refer to Section 6.2.3.
- Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way). The green LED on the rear panel should flicker as the instrument is receiving data.
- Ensure that the communications software is functioning properly.

Further help with serial communications is available in a separate manual “RS-232 Manual”, Teledyne API’s P/N 013500000, available online at <http://www.Teledyne-api.com/manuals/>.

### 11.6.10. SHUTTER SYSTEM

To check the functionality of the UV light Shutter by manually activating it:

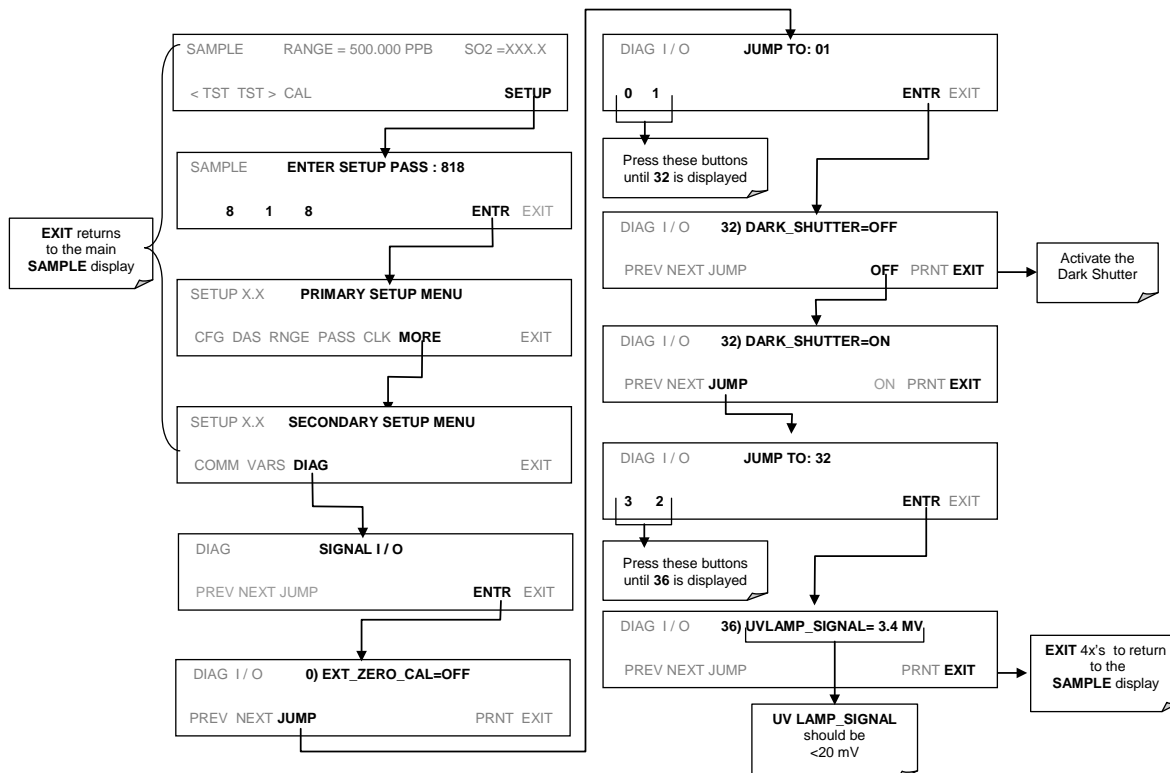


Figure 11-5: Manual Activation of the UV Light Shutter

### 11.6.11. PMT SENSOR

The photo multiplier tube detects the light emitted by the UV excited fluorescence of SO<sub>2</sub>. It has a gain of about 500000 to 1000000. It is not possible to test the detector outside of the instrument in the field. The best way to determine if the PMT is working properly is by using the optical test (**OTEST**), which is described in Section 5.9.4. The basic method to diagnose a PMT fault is to eliminate the other components using **ETEST**, **OTEST** and specific tests for other sub-assemblies.

### 11.6.12. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, we suggest the technician carry out the electrical and optical tests described in 5.9.4 and 5.9.5.

If the **ETEST** fails, the preamplifier board may be faulty.

### 11.6.13. PMT TEMPERATURE CONTROL PCA

The TEC control printed circuit assembly is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan.

- If the red LED located on the top edge of this assembly is not glowing the control circuit is not receiving power.
- Check the analyzer's power supply, the relay board's power distribution circuitry and the wiring connecting them to the PMT temperature control PCA.

#### 11.6.13.1. TEC CONTROL TEST POINTS

Four test points are also located at the top of this assembly they are numbered left to right start with the T1 point immediately to the right of the power status LED. These test points provide information regarding the functioning of the control circuit.

To determine the current running through the control circuit, measure the voltage between **T1** and **T2**. Multiply that voltage by 10.

To determine the drive voltage being supplied by the control circuit to the TEC, measure the voltage between **T2** and **T3**.

- If this voltage is zero, the TEC circuitry is most likely open.
- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 and T2 = 0 VDC there is most likely an open circuit or failed op amp on control PCA itself
- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 to T2 is some voltage other than 0 VDC, the TEC is most likely shorted

**T4** is tied directly to ground. To determine the absolute voltage on any one of the other test points make a measurement between that test point and T4.

### 11.6.14. HIGH VOLTAGE POWER SUPPLY

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube (refer to Figure 12-17). It requires 2 voltage inputs. The first is +15 which powers the supply. The second is the programming voltage which is generated on the Preamp Board. This power supply is unlike a traditional PMT HVPS. It is like having 10

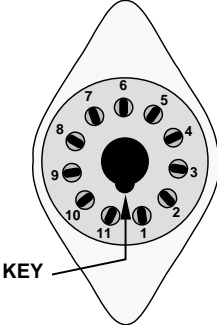


independent power supplies, one to each pin of the PMT. The test procedure below allows you to test each supply.

1. Check the **HVPS** test function via the front panel and record the reading level. Adjustment of the HVPS output level is covered in the hardware calibration procedure in Section 11.7.2.8.
2. Turn off the instrument.
3. Remove the cover and disconnect the 2 connectors at the front of the PMT housing.
4. Remove the end plate from the PMT housing.
5. Remove the HVPS/PMT assembly from the cold block inside the sensor. Un-plug the PMT.
6. Re-connect the 7 pin connector to the Sensor end cap, and power-up the instrument.
7. Check the voltages between the pairs of pins listed in Table 11-9. The result for each pair should be equal and approximately 10% of the reading level recorded in Step 1.

**Table 11-9: Example of HVPS Power Supply Outputs**

If HVPS reading = 700 VDC	
PIN PAIR	NOMINAL READING
1 → 2	70 VDC
2 → 3	70 VDC
3 → 4	70 VDC
4 → 5	70 VDC
5 → 6	70 VDC
6 → 7	70 VDC
7 → 8	70 VDC



8. Turn off the instrument power, and re-connect the PMT tube, and then re-assemble the sensor.

If any faults are found in the test, the HVPS must be replaced. There are no user serviceable parts inside the HVPS.

### 11.6.15. PNEUMATIC SENSOR ASSEMBLY

The pressure/flow sensor circuit board, located behind the sensor assembly, can be checked with a voltmeter using the following procedure, which assumes that the wiring is intact and that the motherboard and the power supplies are operating properly.

- Measure the voltage across TP1 and TP2, it should be  $10.0 \pm 0.25$  V. If not, the board may be faulty.
- Measure the voltage across capacitor C2; it should be  $5.0 \pm 0.25$  V. If not, the board may be faulty.

### 11.6.16. SAMPLE PRESSURE

Measure the voltage across test points TP1 and TP4. With the sample pump disconnected or turned off, this voltage should be  $4500 \pm 250$  mV. With the pump running, it should be about 0.2 V less as the sample pressure drops by about 1 in-Hg-A from ambient pressure. If this voltage is significantly different, the pressure transducer S2 or the board may be faulty. A leak in the sample system to vacuum may also cause this voltage to be between about 0.6 and 4.5. Ensure that the front panel reading of the sample pressure is at about 1 in-Hg-A less than ambient pressure.

### 11.6.17. IZS OPTION

The zero/span valves and IZS options need to be enabled in the software (contact the factory on how to do this). Refer to Figure 3-19 and Figure 3-21 for a flow diagram with zero/span valve or IZS option.

- Check for the physical presence of the valves or the IZS option.
- Check that a working perm-tube is installed in the IZS oven assembly.
- Check front panel for correct software configuration. When the instrument is in SAMPLE mode, the front panel display should show CALS and CALZ buttons in the second line of the display. The presence of the buttons indicates that the option has been enabled in software. In addition, the IZS option is enabled if the TEST functions show a parameter named IZS TEMP.

The IZS option is heated with a proportional heater circuit and the temperature is maintained at  $50^{\circ}\text{C} \pm 1^{\circ}$ . Check the **IZS TEMP** function via front panel display (refer to Section 4.1.1) and the **IZS\_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (refer to Section 5.9.1).

At  $50^{\circ}\text{C}$ , the temperature signal from the IZS thermistor should be around 2500 mV.

### 11.6.18. BOX TEMPERATURE

The box temperature sensor (thermistor) is mounted on the motherboard at the bottom, right corner of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance. Box temperature will vary with, but will always read about  $5^{\circ}\text{C}$  higher than, ambient (room) temperature because of the internal heating zones sample chamber and other devices.

To check the box temperature functionality, we recommend checking the **BOX\_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (refer to Section 5.9.1).

At about  $30^{\circ}\text{C}$  ( $5^{\circ}$  above typical room temperature), the signal should be around 1500 mV. We recommend using a certified or calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature.

### 11.6.19. PMT TEMPERATURE

PMT temperature should be low and constant. It is more important that this temperature is maintained constant than it is to maintain it low. The PMT cooler uses a Peltier, thermo-electric element powered by 12 VDC from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board. Voltages applied to the cooler element vary from  $\pm 0.1$  to  $\pm 12$

VDC. The temperature set point (hard-wired into the preamplifier board) will vary by about  $\pm 1^{\circ}\text{C}$  due to component tolerances. The actual temperature will be maintained to within  $0.1^{\circ}\text{C}$  around that set point.

On power-up of the analyzer, the front panel enables the user to watch that temperature drop from about ambient temperature down to its set point of  $6\text{-}8^{\circ}\text{C}$ .

- If the temperature fails to drop after 20 minutes, there is a problem in the cooler circuit.
- If the control circuit on the preamplifier board is faulty, a temperature of  $-1^{\circ}\text{C}$  is reported.

## 11.7. SERVICE PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement.

### ATTENTION

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#### COULD DAMAGE INSTRUMENT AND VOID WARRANTY

**Servicing of circuit components requires electrostatic discharge protection (ESD), i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty.**

**Refer to to the manual on Fundamentals of ESD, PN 04786, which can be downloaded from our website at <http://www.teledyne-api.com> under Help Center > Product Manuals in the Special Manuals section.**

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### 11.7.1. DISK-ON-MODULE REPLACEMENT

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it also may cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM
2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.
3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.
4. The DOM should carry a label with firmware revision, date and initials of the programmer.
5. Remove the nylon fastener that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.

6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.
7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the DOM all the way in and reinsert the offset clip.
8. Close the rear panel and turn on power to the machine.
9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

## 11.7.2. SENSOR MODULE REPAIR &amp; CLEANING

**CAUTION - GENERAL SAFETY HAZARD**

Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).

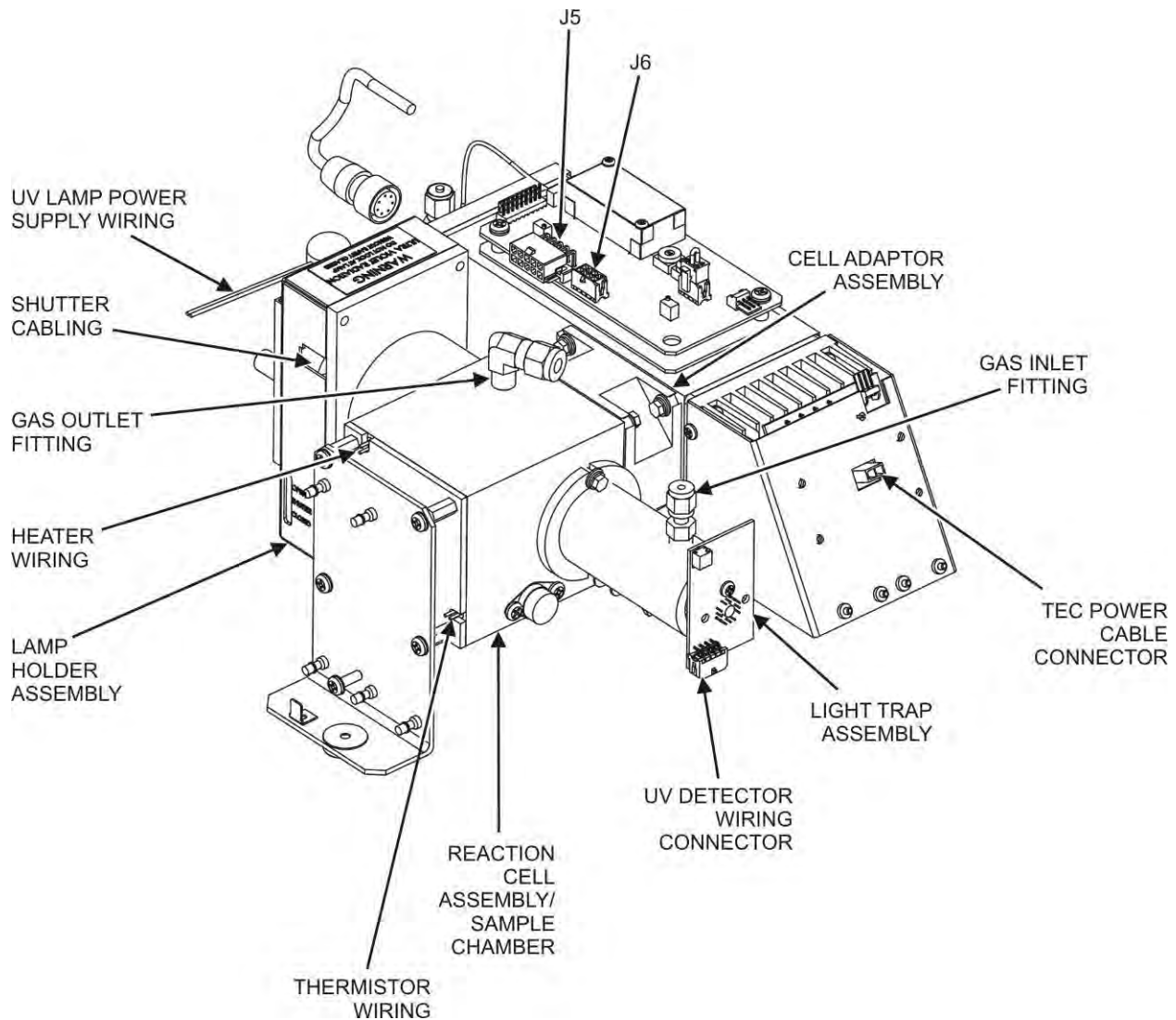


Figure 11-6: Sensor Module Wiring and Pneumatic Fittings

**IMPORTANT****IMPACT ON READINGS OR DATA**

After any repair or service has been performed on the sensor module, the T100 should be allowed to warm up for 60 minutes.

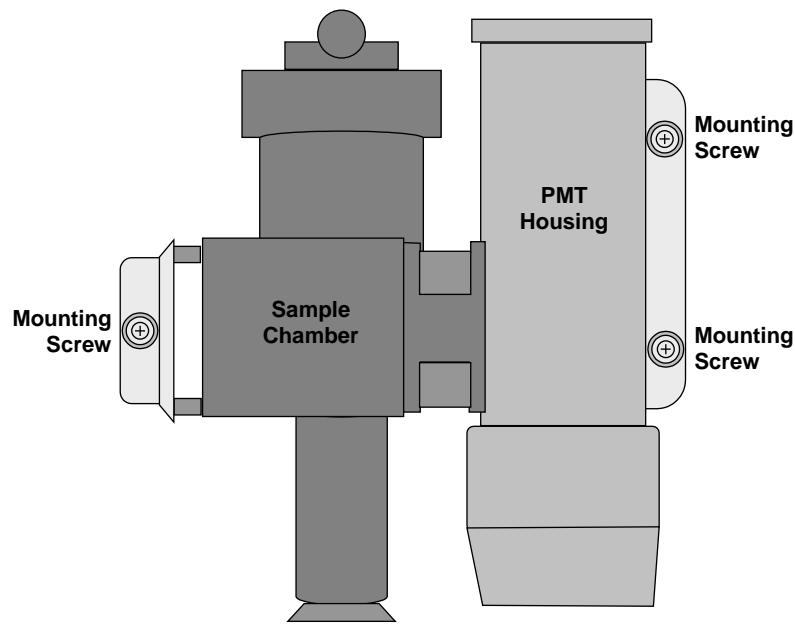
Always perform a leak check (refer to Section 10.3.6) and calibrate the analyzer (refer to Section 9) before placing it back in service.

### 11.7.2.1. REMOVING AND REINSTALLING THE SENSOR MODULE

Several of the procedures in this section either require the sensor module to be removed from the instrument or are easier to perform if it has been removed.

To remove the Sensor Module:

1. Turn off the instrument power.
2. Open the top cover of the instrument:
  - Remove the set screw located in the top, center of the rear panel.
  - Remove the screws fastening the top cover to the unit (four per side).
  - Lift the cover straight up.
3. Disconnect the sensor module pneumatic lines (refer to Figure 11-6)
  - Gas inlet line: 1/8" black Teflon® line with stainless steel fitting.
  - Gas outlet line: 1/4" black Teflon® line with brass fitting.
4. Disconnect all electrical wiring to the Sensor Module:
  - UV lamp power supply wiring
  - Shutter cabling
  - Reaction cell thermistor wiring (yellow)
  - Reaction cell heater wiring (red)
  - UV detector wiring
  - TEC power cable
  - PMT wiring (connectors J5 & J6 on the PMT preamplifier PCA)
5. Remove the three sensor module mounting screws.



**Figure 11-7: Sensor Module Mounting Screws**

Follow the above steps in reverse order to reinstall the sensor module.

### 11.7.2.2. CLEANING THE SAMPLE CHAMBER

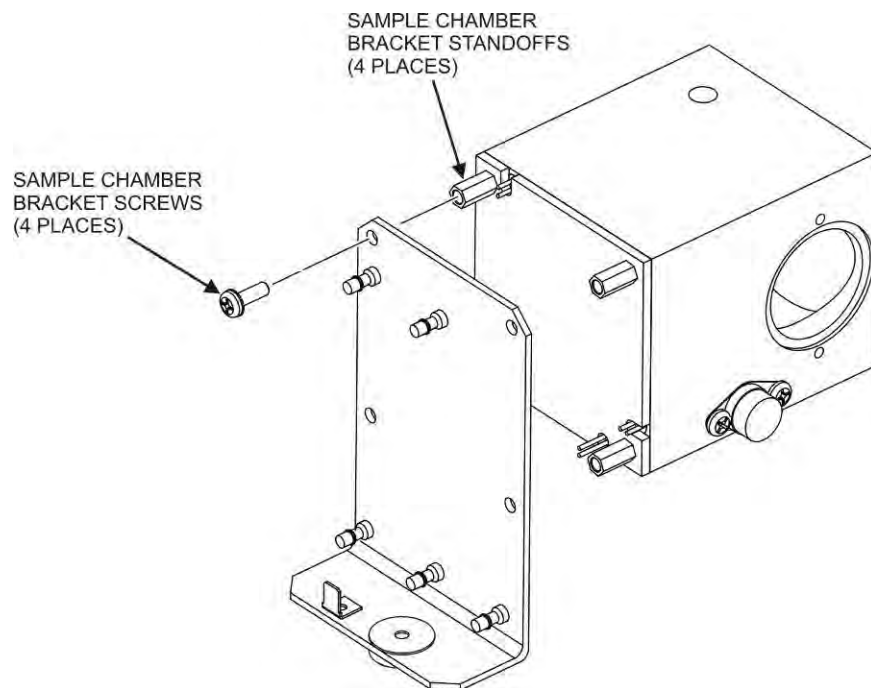
**IMPORTANT****IMPACT ON READINGS OR DATA**

The sample chamber should only be opened or cleaned on instructions from the Teledyne API Technical Support department.

Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO<sub>2</sub> measurement)

To clean the sample chamber:

1. Remove the sensor module as described in Section 11.7.2.1.
2. Remove the sample chamber mounting bracket by unscrewing the four bracket screws.



**Figure 11-8: Sample Chamber Mounting Bracket**

3. Unscrew the 4 hexagonal standoffs.
4. Gently remove the chamber cover.
5. Using a lint-free cloth dampened with distilled water, wipe the inside surface of the chamber and the chamber cover.
6. Dry the chamber surfaces with a 2nd lint-free cloth.
7. Re-assemble the chamber and re-install the sensor module.

11.7.2.3. CLEANING THE PMT LENS AND PMT FILTER

**IMPORTANT**

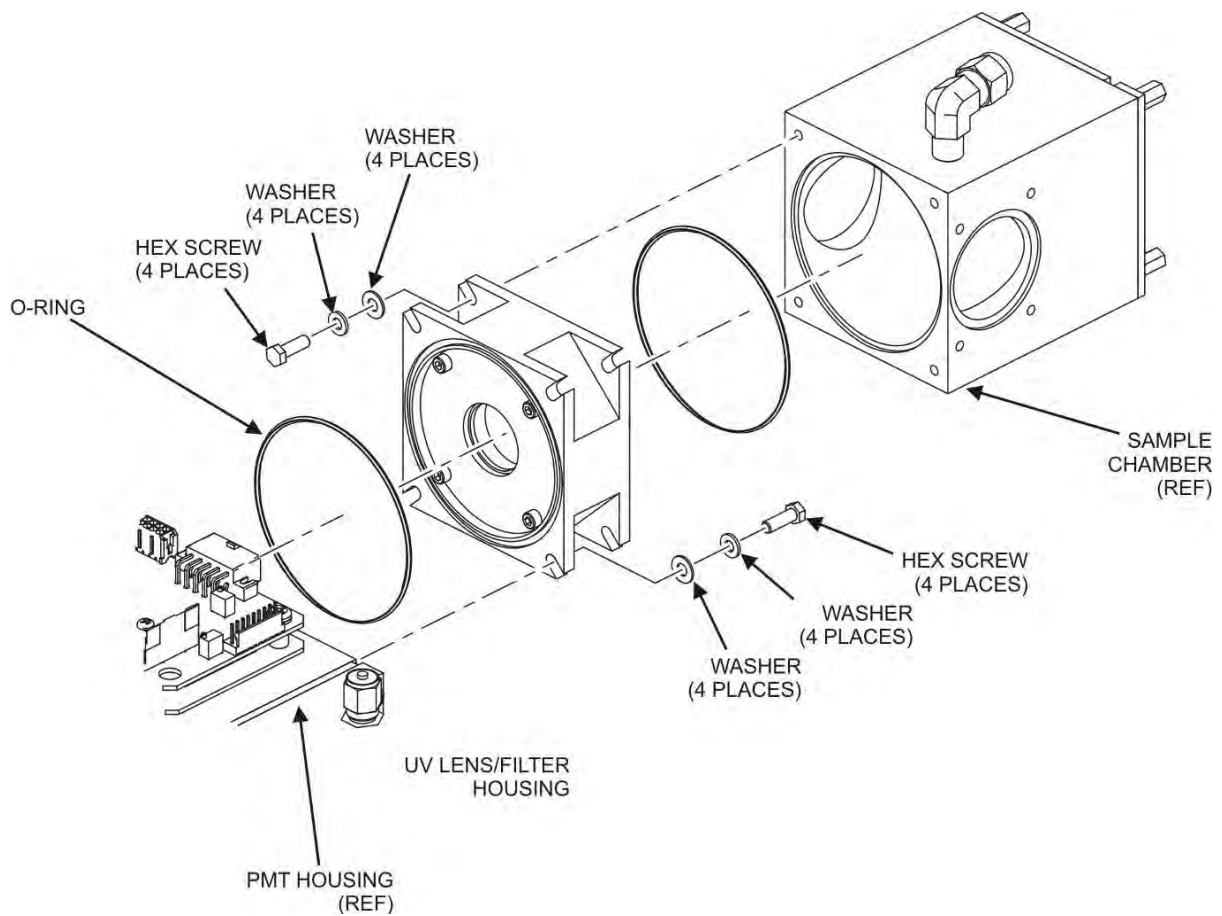
**IMPACT ON READINGS OR DATA**

The sample chamber should only be opened or cleaned on instructions from the Teledyne API Technical Support Department.

Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO<sub>2</sub> measurement).

To clean the PMT Lens and filter:

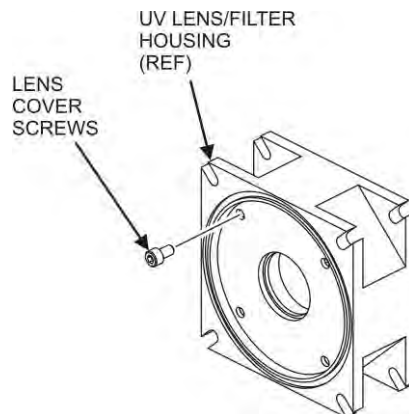
1. Remove the sensor module as described in Section 11.7.2.1.



**Figure 11-9: Hex Screw Between Lens Housing and Sample Chamber**

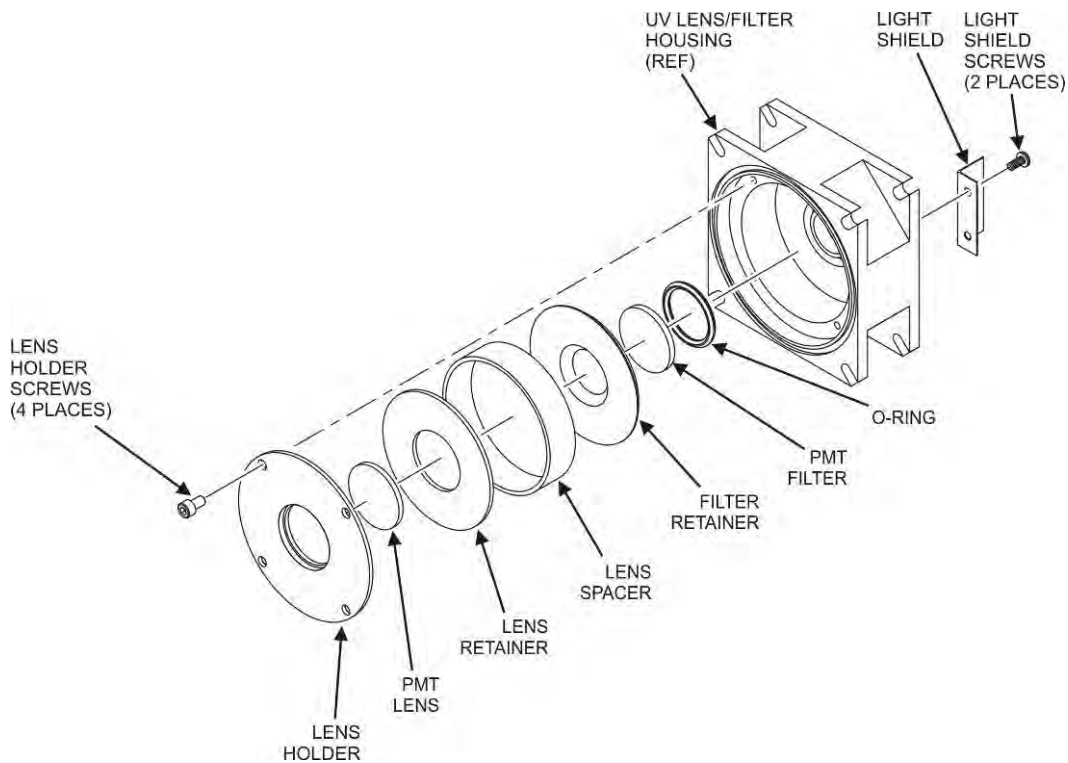


2. Remove the sample chamber from the PMT lens and filter housing by unscrewing the 4 hex screws that fasten the chamber to the housing.
3. Remove the four lens cover screws.



**Figure 11-10: UV Lens Housing / Filter Housing**

4. Remove the lens/filter cover.
5. Carefully remove the PMT lens and set it aside on soft, lint-free cloth.
6. Remove the 3-piece, lens/filter spacer.
7. Carefully remove the PMT filter and set it aside on soft, lint-free cloth.



**Figure 11-11: PMT UV Filter Housing Disassembled**

8. Using a lint-free cloth dampened with distilled water, clean the lens, the filter and all of the housing assembly mechanical parts.
9. Dry everything with a 2nd lint-free cloth.
10. Reassemble the lens/filter housing (refer to Figure 11-11 and Figure 11-10).

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

**Use gloves and a clean plastic covered surface during assembly. Cleanliness of the inside of the light shield, the UV lens filter housing and the PMT lens is especially important.**

**Note**

**Ensure to apply Loctite to the four lens holder screws and the two light shield screws.**

11. Reattach the lens / filter housing to the sample chamber.
12. Reattach the sample chamber to the PMT housing.
13. Reinstall the sensor module into the T100.
14. Close the instrument.
15. Turn the T100 on and let it warm up for 60 minutes.
16. Perform a leak check (refer to Section 10.3.6).
17. Calibrate the analyzer (refer to Section 9).

**11.7.2.4. REPLACING THE UV FILTER/LENS**

**IMPORTANT**

**IMPACT ON READINGS OR DATA**

**Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO<sub>2</sub> measurement).**

**CAUTION - GENERAL SAFETY HAZARD**

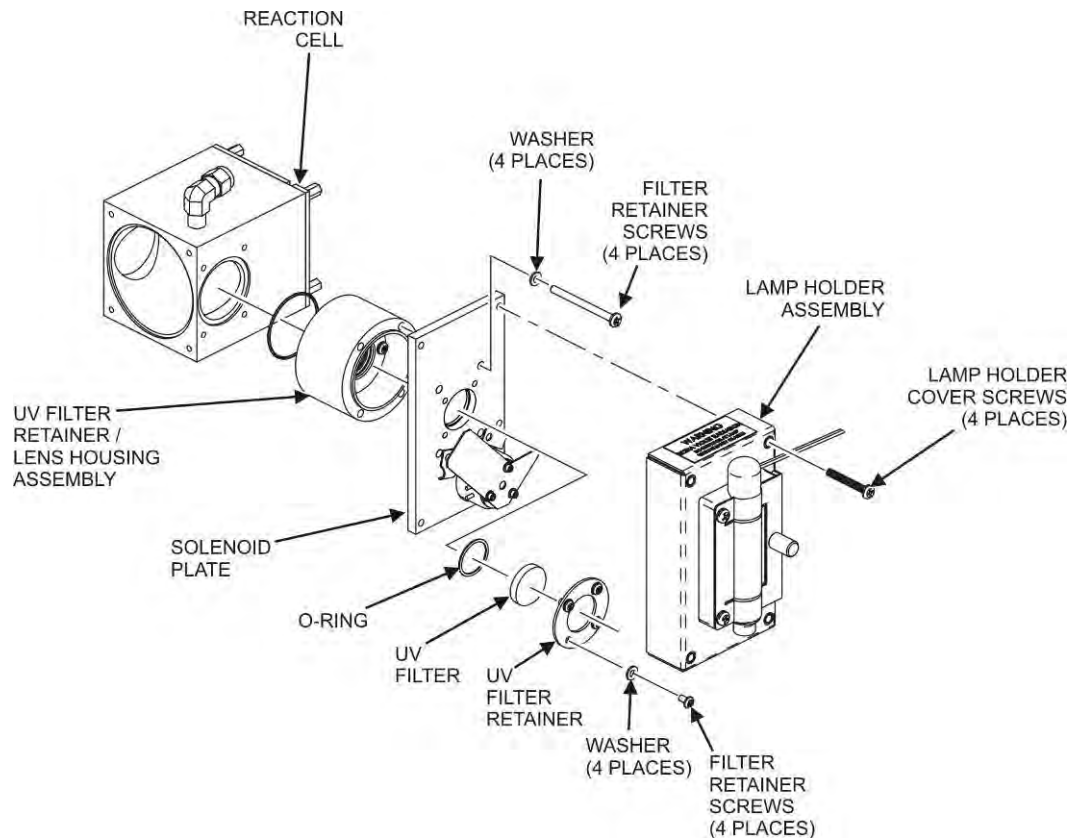


**Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).**

To replace the UV filter lens:

1. Turn off the instrument's power and remove the power cord from the instrument.
2. Unplug J4 connector from the motherboard to allow tool access.
3. Alternatively, remove the sensor module as described in Section 11.7.2.1.

4. Remove 4 screws from the shutter cover (refer to Figure 11-13) and remove the cover.
5. Remove 4 screws from the UV filter retainer.



**Figure 11-12: Disassembling the Shutter Assembly**

6. Carefully remove the UV filter.
7. Install the UV filter.
8. Handle carefully and never touch the filter's surface.
9. UV filter's wider ring side should be facing out.
10. Install UV filter retainer and tighten screws.
11. Install the shutter cover and minifit connector. Tighten 4 shutter cover screws.
12. Reinstall the sensor module and Plug J4 connector into the motherboard.

#### 11.7.2.5. ADJUSTING THE UV LAMP (*PEAKING THE LAMP*)

There are three ways in which ambient conditions can affect the UV Lamp output and therefore the accuracy of the SO<sub>2</sub> concentration measurement. These are:

**Line Voltage Change:** UV lamp energy is directly proportional to the line voltage. This can be avoided by installing adequate AC Line conditioning equipment such as a UPS/surge suppressor.

**Lamp Aging** - Over a period of months, the UV energy will show a downward trend and can be up to 50% in the first 90 days, and then a slower rate, until the end of useful life of the lamp. Periodically running the UV lamp calibration routine (refer to Section 5.9.6) will compensate for this until the lamp output becomes too low to function at all.

**Note**

**As the lamp degrades over time, the software for the CPU compensates for the loss of UV output.**

**Lamp Positioning** – The UV output level of the lamp is not even across the entire length of the lamp. Some portions of the lamp shine slightly more brightly than others. At the factory the position of the UV lamp is adjusted to optimize the amount of UV light shining through the UV filter/lens and into the reaction cell. Changes to the physical alignment of the lamp can affect the analyzers ability to accurately measure SO<sub>2</sub>.

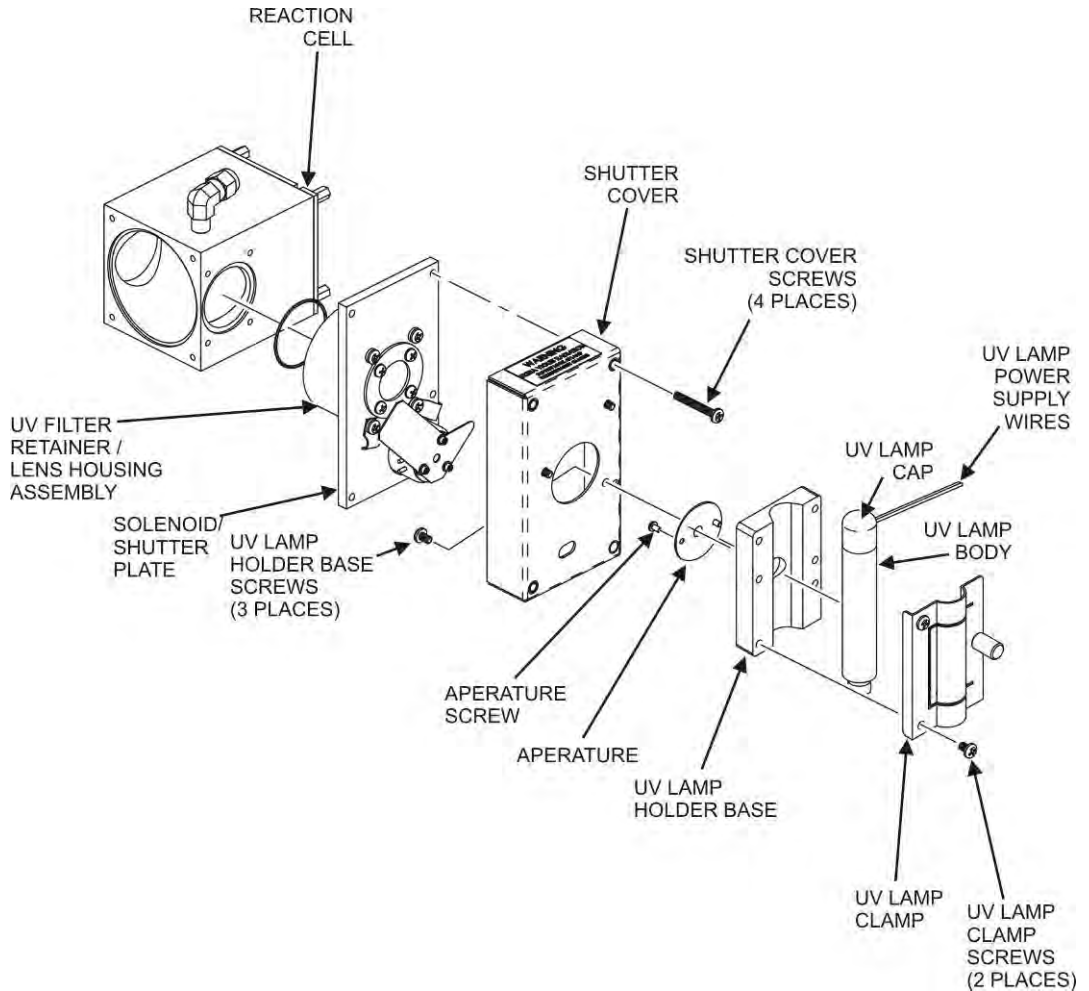


Figure 11-13: Shutter Assembly

**CAUTION - GENERAL SAFETY HAZARD**



**Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).**

1. Set the analyzer display to show the signal I/O function, **UVLAMP\_SIGNAL** (refer to Section 11.1.3). **UVLAMP\_SIGNAL** is function 33.
2. Slightly loosen the large brass thumbscrew located on the shutter housing (refer to Figure 11-14) so that the lamp can be moved.

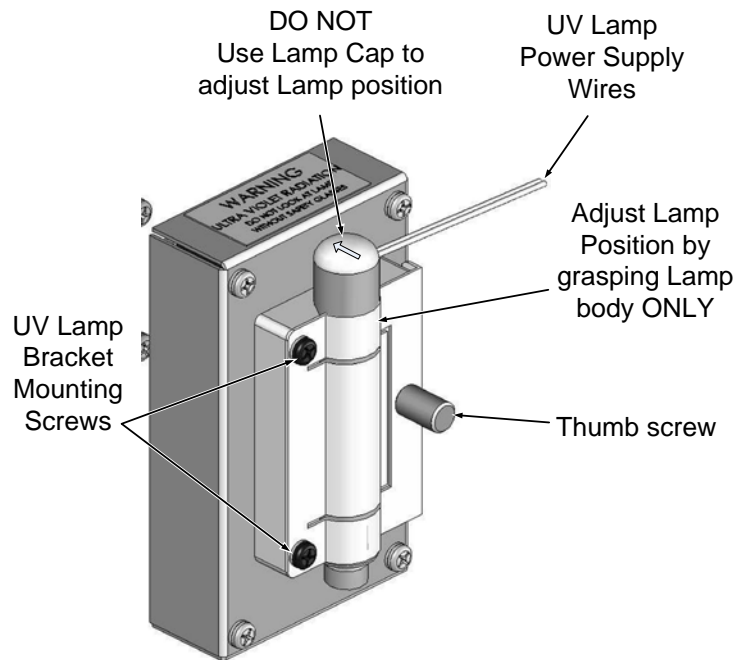


Figure 11-14. UV Lamp Adjustment

**ATTENTION**

-----  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**  
**DO NOT grasp the UV lamp by its cap when changing its position - always grasp the main body of the lamp (refer to Figure 11-13). Inattention to this detail could twist and potentially disconnect the lamp's power supply wires.**  
 -----

3. While watching the **UVLAMP\_SIGNAL** reading, slowly rotate the lamp or move it back and forth vertically until the **UVLAMP\_SIGNAL** reading is at its maximum.
4. Compare the **UVLAMP\_SIGNAL** reading to the information in Table 11-10 and follow the instructions there.

Table 11-10: UV Lamp Signal Troubleshooting

UVLAMP_SIGNAL	ACTION TO BE TAKEN
3500mV±200mV.	No Action Required
> 4900mV at any time.	Adjust the UV reference detector potentiometer (Figure 11-15) until <b>UVLAMP_SIGNAL</b> reads approximately 3600mV before continuing to adjust the lamp position.
>3700mV or < 3300mV	Adjust the UV reference detector potentiometer (Figure 11-15) until <b>UVLAMP_SIGNAL</b> reads as close to 3500mV as possible.
.< 600mV	Replace the lamp (Section 11.7.2.6.

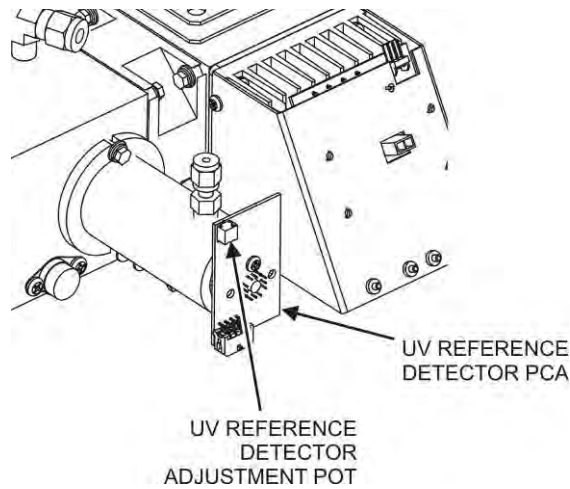


Figure 11-15: Location of UV Reference Detector Potentiometer

5. Finger tighten the thumbscrew.



**CAUTION - GENERAL SAFETY HAZARD**

**DO NOT** over tighten the thumbscrew, as over-tightening can cause breakage to the lamp and consequently release mercury into the area.

11.7.2.6. REPLACING THE UV LAMP



**CAUTION - GENERAL SAFETY HAZARD**

**Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).**

1. Turn off the analyzer.
2. Disconnect the UV lamp from its power supply.
3. You can find the power supply connector by following the two, white UV Lamp power supply wires from the lamp to the power supply.
4. Loosen, but do not remove the two UV lamp bracket screws and the large brass thumbscrew located (refer to Figure 11-13 and Figure 11-14) on the shutter housing so that the lamp can be moved.

**ATTENTION**

**-----**  
**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

**DO NOT** grasp the UV lamp by its cap when changing its position - always grasp the main body of the lamp (refer to Figure 11-13) Inattention to this detail could twist and potentially disconnect the lamp's power supply wires.

**-----**

5. Remove the UV Lamp by pulling it straight up.

6. Insert the new UV lamp into the bracket.
7. Tighten the two UV lamp bracket screws, but leave the brass thumb screw un-tightened.
8. Connect the new UV lamp to the power supply.
9. Turn the instrument on and perform the UV adjustment procedure as defined in section 11.7.2.5.
10. Finger tighten the thumbscrew.

**CAUTION - GENERAL SAFETY HAZARD**

**DO NOT over tighten the thumbscrew, as over-tightening can cause breakage to the lamp and consequently release mercury into the area.**

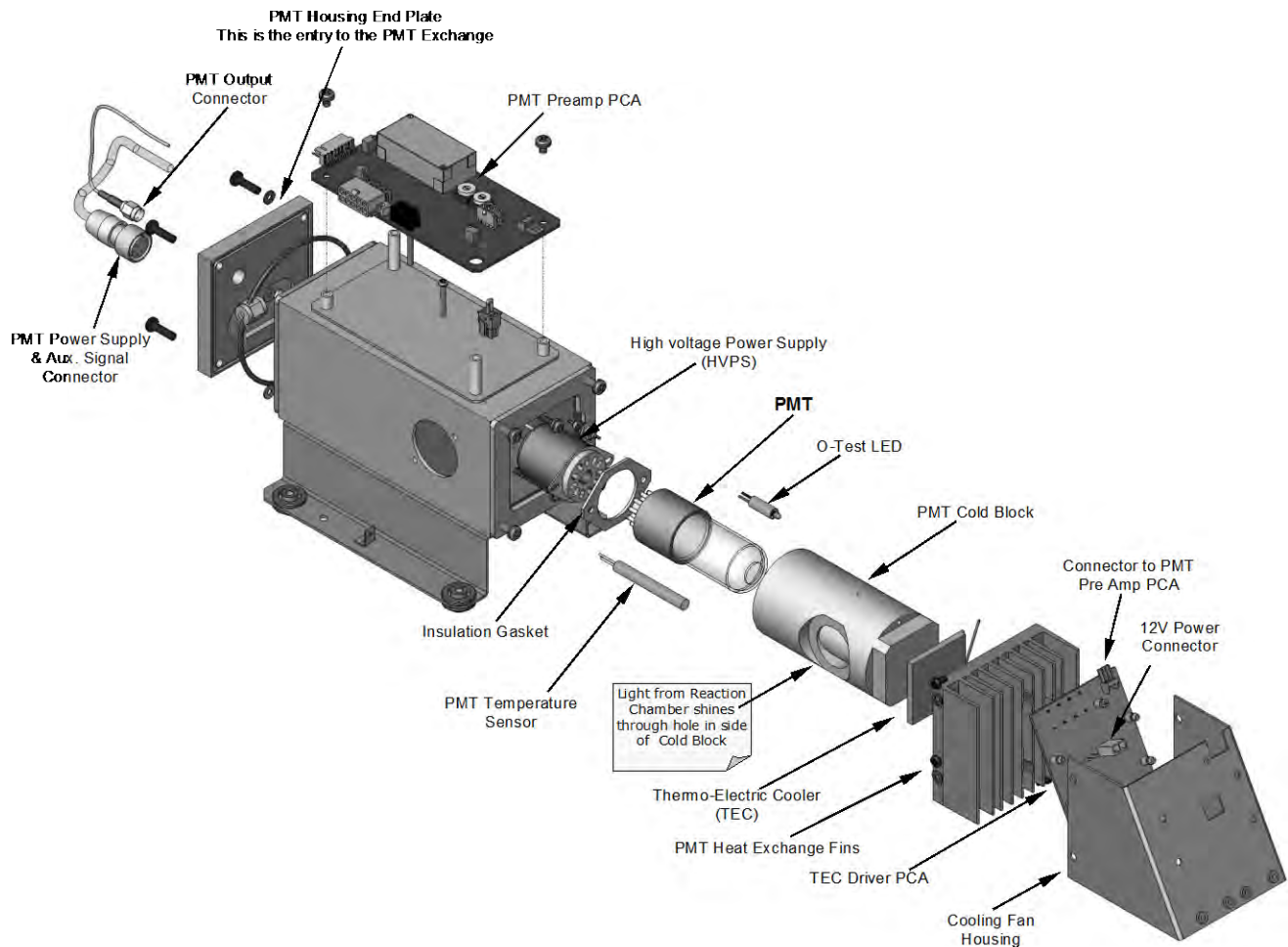
11. Perform a lamp calibration procedure (refer to Section 5.9.6) and a zero point and span point calibration (refer to Section 9).

**11.7.2.7. REPLACING THE PMT, HVPS OR TEC**

The PMT should last for the lifetime of the analyzer. However, in some cases, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) may fail.

**IMPORTANT**

**When removing the PMT housing end plate cover for the Sensor Assembly, ensure to replace the 5 desiccant bags inside the housing.**



**Figure 11-16: PMT Assembly - Exploded View**

To replace the PMT, the HVPS or the TEC:

1. Remove the sensor module as described in Section 11.7.2.1.
2. Remove the entire sensor module assembly from the.
3. Remove the reaction cell assembly.
4. Remove the two connectors on the PMT housing end plate facing towards the front panel.
5. Remove the end plate itself (4 screws with plastic washers).
6. Remove the desiccant bags inside the PMT housing.
7. Along with the plate, slide out the OPTIC TEST LED and the thermistor that measures the PMT temperature.
  - Both may be coated with a white, thermal conducting paste. Do not contaminate the inside of the housing or the PMT tube with this grease.
8. Unscrew the PMT assembly. It is held to the cold block by two plastic screws.
  - Because the threads of the plastic screws are easily damaged it is highly recommended to use new screws when reassembling the unit.
9. Carefully take out the assembly consisting of the HVPS, the gasket and the PMT.



10. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and **DO NOT TOUCH** it after cleaning.
11. If the cold block or TEC is to be changed disconnect the TEC driver board from the preamplifier board.
  - Remove the cooler fan duct (4 screws on its side) including the driver board.
  - Disconnect the driver board from the TEC and set the sub-assembly aside.
  - Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.
  - Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.
12. Re-assemble the TEC subassembly in reverse order.

---

**ATTENTION**

---

**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

**The thermo-electric cooler needs to be mounted flat to the heat sink. If there is any significant gap, the TEC might burn out. Ensure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.**

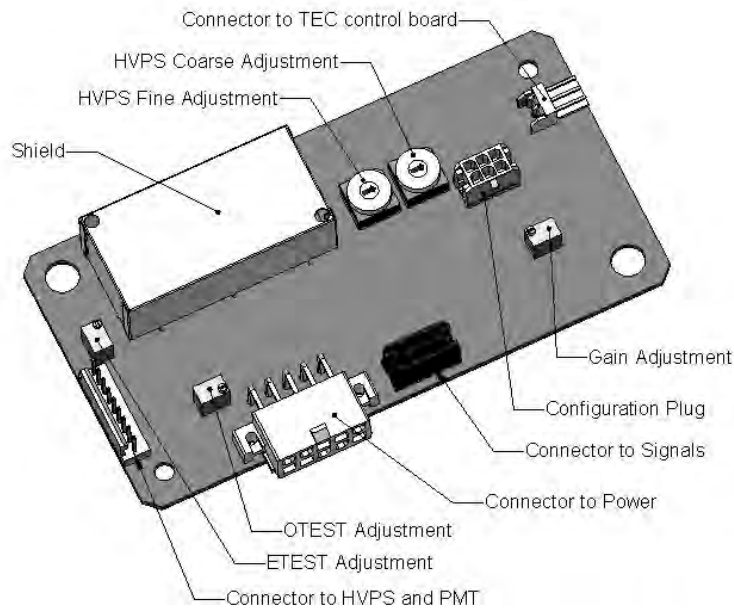
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- Ensure to use thermal grease between TEC and cooling fins as well as between TEC and cold block.
  - Align the side opening in the cold block with the hole in the PMT housing where the sample Chamber attaches.
  - Evenly tighten the long mounting screws for good thermal conductivity.
13. Re-insert the TEC subassembly. Ensure that the O-ring is placed properly and the assembly is tightened evenly.
  14. Re-insert the PMT/HVPS subassembly.
    - Don't forget the gasket between HVPS and PMT.
    - Use new plastic screws to mount the PMT assembly on the PMT cold block.
  15. Insert the LED and thermistor into the cold block.
  16. Replace the desiccant bags with five new desiccant bags.
  17. Carefully replace the end plate.
    - Ensure that the O-ring is properly in place. Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler causing the HVPS to short out.
  18. Reconnect the cables and the reaction cell
    - Be sure to tighten these screws evenly.
  19. Replace the sensor assembly into the chassis and fasten with four screws and washers.
  20. Perform a leak check the system.

21. Power up the analyzer and verify the basic operation of the analyzer using the ETEST and OTEST features (refer to Section 5.9.4 and 5.9.5) or by measuring calibrated zero and span gases.
22. Allow the instrument to warm up for 60 minutes.
23. Perform a PMT Hardware calibration (refer to Section 11.7.2.8).
24. Perform a zero point and span calibration (refer to Section 9).

### 11.7.2.8. PMT HARDWARE CALIBRATION (FACTORY CAL)

The sensor module hardware calibration adjusts the slope of the PMT output when the instrument's slope and offset values are outside of the acceptable range and all other more obvious causes for this problem have been eliminated.



**Figure 11-17: Pre-Amplifier Board (Preamp PCA) Layout**

1. Set the instrument reporting range type to **SNGL** (refer to Section 5.4.3.1).
2. Perform a zero-point calibration using zero air (refer to Section 9).
3. Let the instrument stabilize by allowing it to run for one hour.
4. Adjust the UV Lamp (refer to Section 11.7.2.5).
5. Perform a **LAMP CALIBRATION** procedure (refer to Section 5.9.6).
6. Locate the Preamp PCA (refer to Figure 11-16).
7. Locate the Following Components On the Preamp PCA (Figure 11-17):
8. HVPS coarse adjustment switch (Range 0-9, then A-F).
9. HVPS fine adjustment switch (Range 0-9, then A-F).
10. Gain adjustment potentiometer (Full scale is 10 to 12 turns).
11. Set the HVPS coarse adjustment to its minimum setting (0).
12. Set the HVPS fine adjustment switch to its maximum setting (F).

13. Turn the gain adjustment potentiometer clockwise to its maximum setting.
14. Set the front panel display to show **STABIL** (refer to Section 4.1.1).
15. Feed span gas into the analyzer.
16. Wait until the **STABIL** value is below 0.5 ppb.

**IMPORTANT****IMPACT ON READINGS OR DATA**

**Use a span gas equal to 80% of the reporting range.  
Example: for a reporting range of 500 ppb, use a span gas of 400 ppb.**

17. **Scroll** to the **OFFSET** function and record the value.
18. Scroll to the **NORM PMT** value.

**ATTENTION****COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

**Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. This can cause permanent damage to the PMT.**

19. Determine the target **NORM PMT** value according to the following formulas.
  - If the reporting range is set for  $\leq 2,000$  ppb (the instrument will be using the 2,000 ppb physical range):
 
$$\text{Target NORM PMT} = (2 \times \text{span gas concentration}) + \text{OFFSET}$$
  - If the reporting range is set for  $\geq 2,001$  ppb (the instrument will be using the 20,000 ppb physical range):
 
$$\text{Target NORM PMT} = (0.181 \times \text{span gas concentration}) + \text{OFFSET}$$

**EXAMPLE:** If the **OFFSET IS** 33 mV, the Reporting Range is 500 ppb, the span gas should be 400 ppb and the calculation would be:

$$\text{Target NORM PMT} = (2 \times 400) + 33 \text{ mV}$$

$$\text{Target NORM PMT} = 833 \text{ mV}$$
20. Set the HVPS coarse adjustment switch to the lowest setting that will give you more than the target NORM PMT signal from Step 16.
  - The coarse adjustment typically increments the **NORM PMT** signal in 100-300 mV steps.
21. Adjust the HVPS fine adjustment such that the NORM PMT value is at or just above the target NORM PMT signal from Step 16.
22. Continue adjusting the both the coarse and fine switches until norm PMT is as close to (but not below) the target NORM PMT signal from Step 16.
23. Adjust gain adjustment potentiometer until the NORM PMT value is  $\pm 10$  mV of the target level from Step 16.
24. Perform span and zero-point calibrations (refer to Section 9) to normalize the sensor response to its new PMT sensitivity.
25. Review the slope and offset values, and compare them to the values in Table 9-5.

## 11.8. FREQUENTLY ASKED QUESTIONS (FAQS)

The following list contains some of the most commonly asked questions relating to the T100 SO<sub>2</sub> Analyzer.

QUESTION	ANSWER
Why is the <b>ZERO</b> or <b>SPAN</b> button not displayed during calibration?	The T100 disables these buttons when the expected span or zero value entered by the users is too different from the gas concentration actually measured value at the time. This is to prevent the accidental recalibration of the analyzer to an out-of-range response curve.-EXAMPLE: The span set point is 400 ppb but gas concentration being measured is only 50 ppb.-For more information, refer to Section 11.4.4 and Section 11.4.5.
Why does the <b>ENTR</b> button sometimes disappear on the Front Panel Display?	During certain types of adjustments or configuration operations, the <b>ENTR</b> button will disappear if you select a setting that is nonsensical (such as trying to set the 24-hour clock to 25:00:00) or out of the allowable range for that parameter (such as selecting a DAS hold off period of more than 20 minutes).-Once you adjust the setting in question to an allowable value, the <b>ENTR</b> button will re-appear.
How do I enter or change the value of my Span Gas?	Press the <b>CONC</b> button found under the <b>CAL</b> or <b>CALS</b> menus of the main SAMPLE menu to enter the expected SO <sub>2</sub> span concentration.-Refer to Section 3.4.4.1 or for more information.
Why does the analyzer not respond to span gas?	Section 11.4.4 has some possible answers to this question.
Can I automate the calibration of my analyzer?	Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature.-However, the accuracy of the IZS option's permeation tube is ±5%. While this may be acceptable for basic calibration checks, the IZS option is not permitted as a calibration source in applications following US EPA protocols. -To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source. Teledyne API offers a zero air generator Model 701 and a gas dilution calibrator Model T700 for this purpose.
What do I do if the concentration on the instrument's front panel display does not match the value recorded or displayed on my data logger even if both instruments are properly calibrated?	This most commonly occurs for one of the following reasons: -A difference in circuit ground between the analyzer and the data logger or a wiring problem;-A scale problem with the input to the data logger. -The analog outputs of the T100 can be manually adjusted to compensate for either or both of these effects, refer to 5.9.3.4; -The analog outputs are not calibrated, which can happen after a firmware upgrade. -Both the electronic scale and offset of the analog outputs can be adjusted (refer to Section 5.9.3.2). Alternately, use the data logger itself as the metering device during calibrations procedures.
How do I perform a leak check?	Refer to Section 10.3.6.
How do I measure the sample flow?	Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating. The sample flow should be 650 cm <sup>3</sup> /min ±10%. Section 10.3.6 includes detailed instructions on performing a check of the sample gas flow.
How often do I need to change the particulate filter?	Once per week. Table 10-1 contains a maintenance schedule listing the most important, regular maintenance tasks.
What is the averaging time for an T100?	The default averaging time, optimized for ambient pollution monitoring, is 240 seconds for stable concentrations and 20 seconds for rapidly changing concentrations; Refer to 12.7.1 for more information.
My analyzer has the optional, user -configurable analog output channels.	Instructions for this can be found in the Manual Addendum for Configurable Analog Output, PN 06270.

QUESTION	ANSWER
How do I program and use them?	
How long does the sample pump last?	The sample pump should last about one year and the pump diaphragms should to be replaced annually or when necessary. Use the <b>PRES</b> test function displayed via the front panel to see if the diaphragm needs replacement (refer to Section 11.1.2).
Do I need a strip chart recorder or external data logger?	No, the T100 is equipped with a very powerful internal data acquisition system. Section 7 describes the setup and operation in detail.

## 11.9. TECHNICAL ASSISTANCE

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

Teledyne API, Technical Support ,  
9480 Carroll Park Drive  
San Diego, California 92121-5201USA

**Toll-free Phone:** 800-324-5190

**Phone:** 858-657-9800

**Fax:** 858-657-9816

**Email:** [sda\\_techsupport@teledyne.com](mailto:sda_techsupport@teledyne.com)

**Website:** <http://www.teledyne-api.com/>

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

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## 12. PRINCIPLES OF OPERATION

This section describes the principles of operation for the T100 SO<sub>2</sub> analyzer (Section 12.1), for the optional O<sub>2</sub> sensor (Section 12.2) and for the optional CO<sub>2</sub> sensor (Section 12.3). It also describes the principles of operation for pneumatics (Section 12.4), electronics (Section 12.5), communication interfaces (Section 12.6) and software (Section 12.7).

### 12.1. SULFUR DIOXIDE (SO<sub>2</sub>) SENSOR PRINCIPLES OF OPERATION

The T100 UV Fluorescence SO<sub>2</sub> Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO<sub>2</sub>), in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the sample chamber where the sample gas is exposed to ultraviolet light; this exposure causes the SO<sub>2</sub> molecules to change to an excited state (SO<sub>2</sub>\*). As these SO<sub>2</sub>\* molecules decay into SO<sub>2</sub> they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO<sub>2</sub> present in the sample gas.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of SO<sub>2</sub> at various concentrations are supplied and stores these measurements in memory. The microprocessor uses these calibration values along with other performance parameters such as the PMT dark offset, UV lamp ratio and the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO<sub>2</sub> concentration.

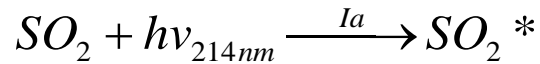
This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system and reported to the user through a vacuum fluorescent display or as electronic data via several communication ports.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system (refer to Section 7) and reported to the user through a vacuum fluorescent display or several communication ports.

#### 12.1.1. SO<sub>2</sub> ULTRAVIOLET FLUORESCENCE MEASUREMENT PRINCIPLE

The physical principle upon which the T100's measurement method is based is the fluorescence that occurs when sulfur dioxide (SO<sub>2</sub>) is changed to excited state (SO<sub>2</sub>\*) by ultraviolet light with wavelengths in the range of 190 nm-230 nm. This reaction is a two-step process.

The first stage (Equation 12-1) occurs when SO<sub>2</sub> molecules are struck by photons of the appropriate ultraviolet wavelength. In the case of the T100, a band pass filter between the source of the UV light and the affected gas limits the wavelength of the light to approximately 214 nm. The SO<sub>2</sub> absorbs some of energy from the UV light causing one of the electrons of the SO<sub>2</sub> molecule to move to a higher energy orbital state.



(Equation 12-1)

The amount SO<sub>2</sub> converted to SO<sub>2</sub>\* in the sample chamber is dependent on the average intensity of the UV light (*Ia*) and not its peak intensity because the intensity of UV light is not constant in every part of the sample chamber. Some of the photons are absorbed by the SO<sub>2</sub> as the light travels through the sample gas.

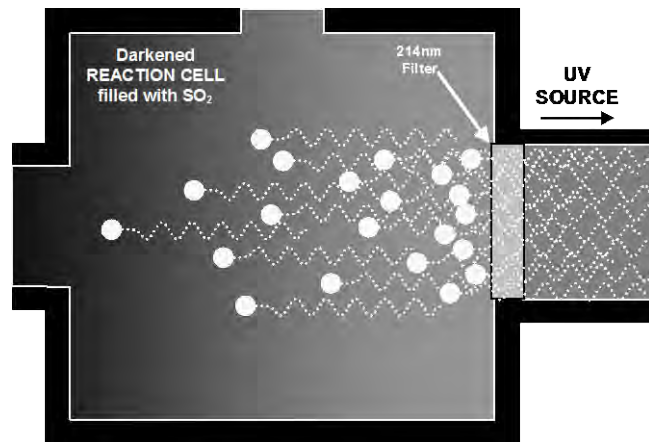


Figure 12-1: UV Absorption

The equation for defining the average intensity of the UV light (*Ia*) is:

$$Ia = I_0 [1 - \exp(-ax(SO_2))]$$

(Equation 12-2)

Where:

*I<sub>0</sub>* = Intensity of the excitation UV light.

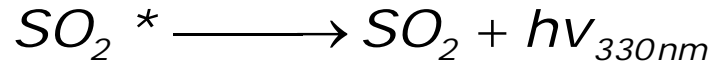
*a* = The absorption coefficient of SO<sub>2</sub> (a constant).

*SO<sub>2</sub>* = Concentration of SO<sub>2</sub> in the sample chamber.

*x* = The distance between the UV source and the SO<sub>2</sub> molecule(s) being affected (path length).



The second stage of this reaction occurs after the SO<sub>2</sub> reaches its excited state (SO<sub>2</sub>\*). Because the system will seek the lowest available stable energy state, the SO<sub>2</sub>\* molecule quickly returns to its ground state (Equation 10-3) by giving off the excess energy in the form of a photon ( $h\nu$ ). The wavelength of this fluoresced light is also in the ultraviolet band but at a longer (lower energy) wavelength centered at 330nm.



(Equation 12-3)

The amount of detectable UV given off by the decay of the SO<sub>2</sub>\* is affected by the rate at which this reaction occurs ( $k$ ).

$$F = k(SO_2^*)$$

(Equation 12-4)

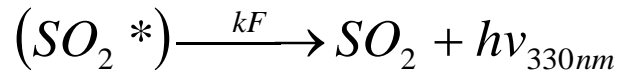
Where:

**F** = the amount of fluorescent light given off.

**k** = The rate at which the SO<sub>2</sub>\* decays into SO<sub>2</sub>.

**SO<sub>2</sub>\*** = Amount of excited-state SO<sub>2</sub> in the sample chamber.

Therefore:



(Equation 12-5)

Finally, the function ( $k$ ) is affected by the temperature of the gas. The warmer the gas, the faster the individual molecules decay back into their ground state and the more photons of UV light are given off per unit of time.

Given that the absorption rate of SO<sub>2</sub> ( $a$ ) is constant, the amount of fluorescence ( $F$ ) is a result of:

- The amount of SO<sub>2</sub>\* created which is affected by the variable factors from (Equation 12-2) above: concentration of SO<sub>2</sub>; intensity of UV light ( $I_0$ ); path length of the UV light( $x$ ) and;
- The amount of fluorescent light created which is affected by the variable factors from (Equation 12-5): the amount of SO<sub>2</sub>\* present and the rate of decay ( $k$ ) which changes based on the temperature of the gas.

When and the intensity of the light ( $I_0$ ) is known; path length of excited light is short ( $x$ ); the temperature of the gas is known and compensated for so that the rate of SO<sub>2</sub>\*decay is constant ( $k$ ). and; no interfering conditions are present (such as interfering gases or stray light); the amount of fluorescent light emitted ( $F$ ) is directly related to the concentration of the SO<sub>2</sub> in the Sample Chamber.

The Model 100 E UV Fluorescence SO<sub>2</sub> Analyzer is specifically designed to create these circumstances.

- The light path is very short ( $x$ ).

- A reference detector measures the intensity of the available excitation UV light and is used to remove effects of lamp drift ( $I_0$ ).
- The temperature of the sample gas is measured and controlled via heaters attached to the sample chamber so that the rate of decay ( $k$ ) is constant.
- A special hydrocarbon scrubber removes the most common interfering gases from the sample gas.
- And finally, the design of the sample chamber reduces the effects of stray light via its optical geometry and spectral filtering.

The net result is that any variation in UV fluorescence can be directly attributed to changes in the concentration of SO<sub>2</sub> in the sample gas.

### 12.1.2. THE UV LIGHT PATH

The optical design of the T100's sample chamber optimizes the fluorescent reaction between SO<sub>2</sub> and UV Light (refer to Figure 12-2) and assure that only UV light resulting from the decay of SO<sub>2</sub>\* into SO<sub>2</sub> is sensed by the instruments fluorescence detector.

UV radiation is generated by a lamp specifically designed to produce a maximum amount of light of the wavelength needed to excite SO<sub>2</sub> into SO<sub>2</sub>\* (214 nm) and a special reference detector circuit constantly measures lamp intensity (refer to (Equation 12-2)). A Photo Multiplier Tube (PMT) detects the UV given off by the SO<sub>2</sub>\* decay (330 nm) and outputs an analog signal. Several focusing lenses and optical filters ensure that both detectors are exposed to an optimum amount of only the right wavelengths of UV. To further assure that the PMT only detects light given off by decaying SO<sub>2</sub>\* the pathway of the excitation UV and field of view of the PMT are perpendicular to each other and the inside surfaces of the sample chamber are coated with a layer of black Teflon<sup>®</sup> that absorbs stray light.

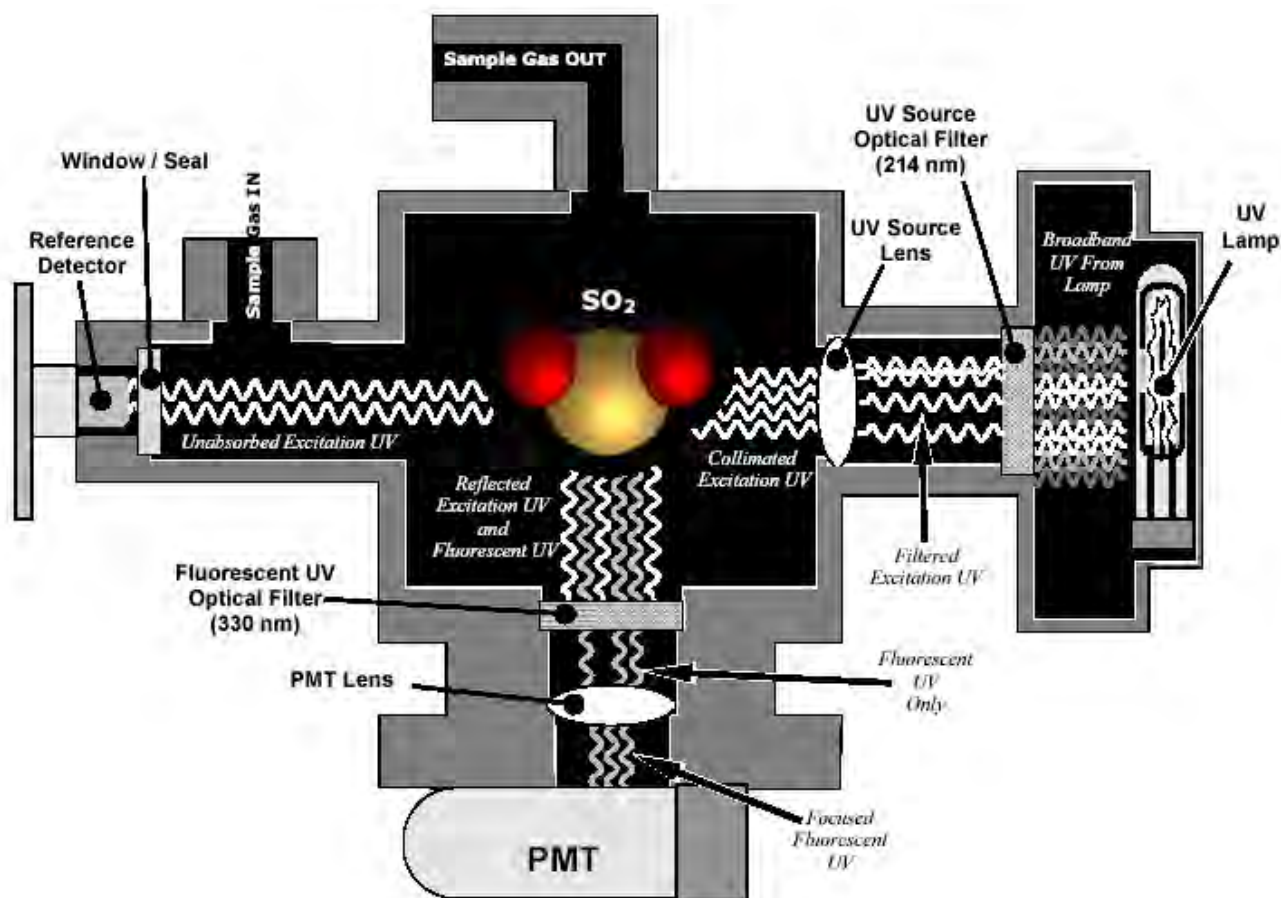


Figure 12-2: UV Light Path

### 12.1.3. UV SOURCE LAMP

The source of excitation UV light for the T100 is a low pressure zinc-vapor lamp. An AC voltage heats up and vaporizes zinc contained in the lamp element creating a light-producing plasma arc. Zinc-vapor lamps are preferred over the more common mercury-vapor lamps for this application because they produce very strong emission levels at the wavelength required to convert SO<sub>2</sub> to SO<sub>2</sub><sup>\*</sup>, 213.9 nm (refer to Figure 12-4).

The lamp used in the T100 is constructed with a vacuum jacket surrounding a double-bore lamp element (refer to Figure 12-3). The vacuum jacket isolates the plasma arc from most external temperature fluctuations. The jacket also contains thermal energy created by the lamp's operation therefore helping the lamp to heat up and maintain proper vaporization temperature. Light is emitted through a 20 mm x 5 mm portal.

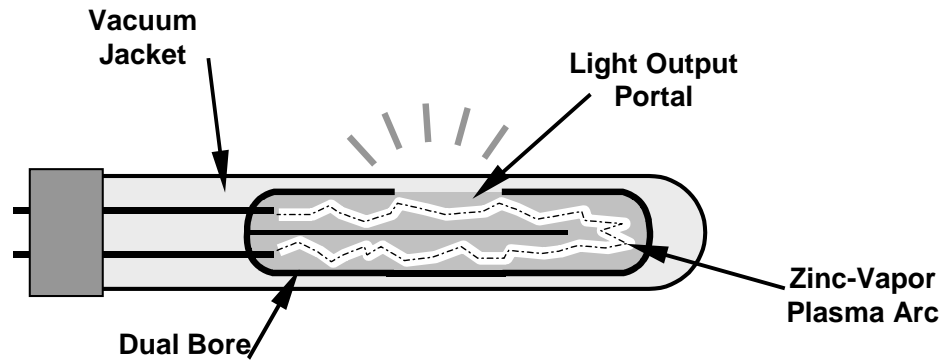


Figure 12-3: Source UV Lamp Construction

#### 12.1.4. THE REFERENCE DETECTOR

A vacuum diode, UV detector that converts UV light to a DC current is used to measure the intensity of the excitation UV source lamp. It is located directly across from the source lamp at the back of a narrow tube-shaped light trap, which places it directly in the path of the excitation UV light. A window transparent to UV light provides an air-proof seal that prevents ambient gas from contaminating the sample chamber. The shape of the light trap and the fact that the detector is blind to wavelengths other than UV no extra optical filtering is needed.

#### 12.1.5. THE PMT

The amount of fluoresced UV produced in the sample chamber is much less than the intensity of excitation UV source lamp (refer to Figure 12-4). Therefore a much more sensitive device is needed to detect this light with enough resolution to be meaningful. The T100 uses a Photo Multiplier Tube or PMT for this purpose.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by a high voltage applied across a series of special electrodes called dynodes that multiply the amount of electrons until a useable current signal is generated. This current increases or decreases with the amount of detected light (refer to Section 12.5.3 for more details regarding the electronic operation of the PMT).

#### 12.1.6. UV LAMP SHUTTER & PMT OFFSET

Inherent in the operation of both the reference detector and the PMT are a minor electronic offsets. The degree of offset differs from detector to detector and from PMT to PMT and can change over time as these components age.

To account for these offsets the T100 includes a shutter, located between the UV Lamp and the source filter that periodically cuts off the UV light from the sample chamber. This happens every 30 minutes. The analyzer records the outputs of both the reference detector and the PMT during this dark period and factors them into the SO<sub>2</sub> concentration calculation.

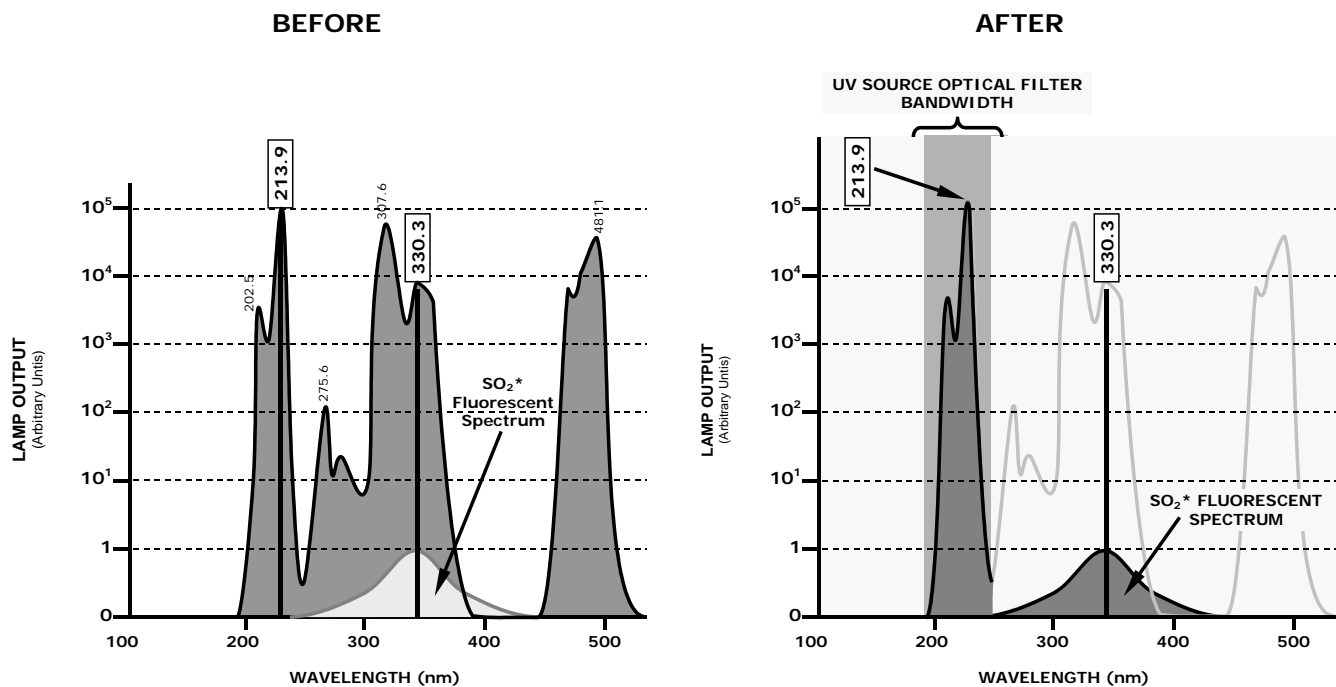
- The reference detector offset is stored as and viewable via the front panel as the test function **DRK LMP**.
- The PMT offset is stored as and viewable via the front panel as the test function **DRK PMT**.

### 12.1.7. OPTICAL FILTERS

The T100 analyzer uses two stages of optical filters to enhance performance. The first stage conditions the UV light used to excite the SO<sub>2</sub> by removing frequencies of light that are not needed to produce SO<sub>2</sub>\*. The second stage protects the PMT detector from reacting to light not produced by the SO<sub>2</sub>\* returning to its ground state.

#### 12.1.7.1. UV SOURCE OPTICAL FILTER

Zinc-vapor lamps output light at other wavelengths beside the 214nm required for the SO<sub>2</sub> → SO<sub>2</sub>\* transformation including a relatively bright light of the same wavelength at which SO<sub>2</sub>\* fluoresces as it returns to its SO<sub>2</sub> ground state (330 nm). In fact, the intensity of light emitted by the UV lamp at 330nm is so bright, nearly five orders of magnitude brighter than that resulting from the SO<sub>2</sub>\* decay, it would drown out the SO<sub>2</sub>\* fluorescence.



**Figure 12-4: Excitation Lamp UV Spectrum Before/After Filtration**

To solve this problem, the light emitted by the excitation UV lamp passes through a band pass filter that screens out photons with wavelengths outside the spectrum required to excite SO<sub>2</sub> into SO<sub>2</sub>\* (refer to Figure 12-4).

### 12.1.7.2. PMT OPTICAL FILTER

The PMT used in the T100 reacts to a wide spectrum of light which includes much of the visible spectrum and most of the UV spectrum. Even though the 214 nm light used to excite the SO<sub>2</sub> is focused away from the PMT, some of it scatters in the direction of the PMT as it interacts with the sample gas. A second optical band pass filter placed between the sample chamber (refer to Figure 12-2) and the PMT strips away light outside of the fluorescence spectrum of decaying SO<sub>2</sub>\* (refer to Figure 12-5) including reflected UV from the source lamp and other stray light.

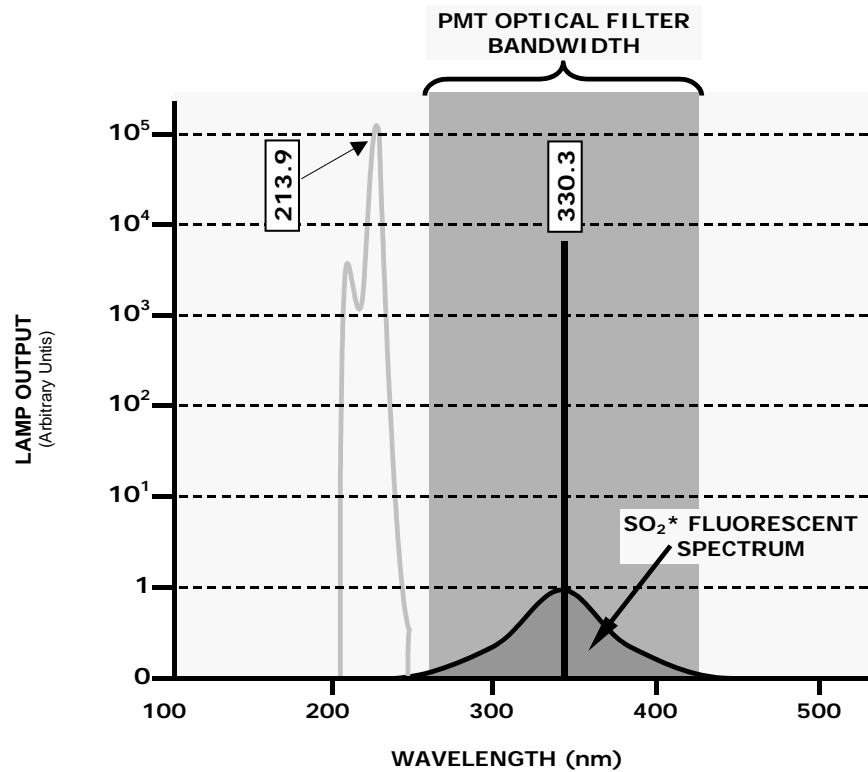
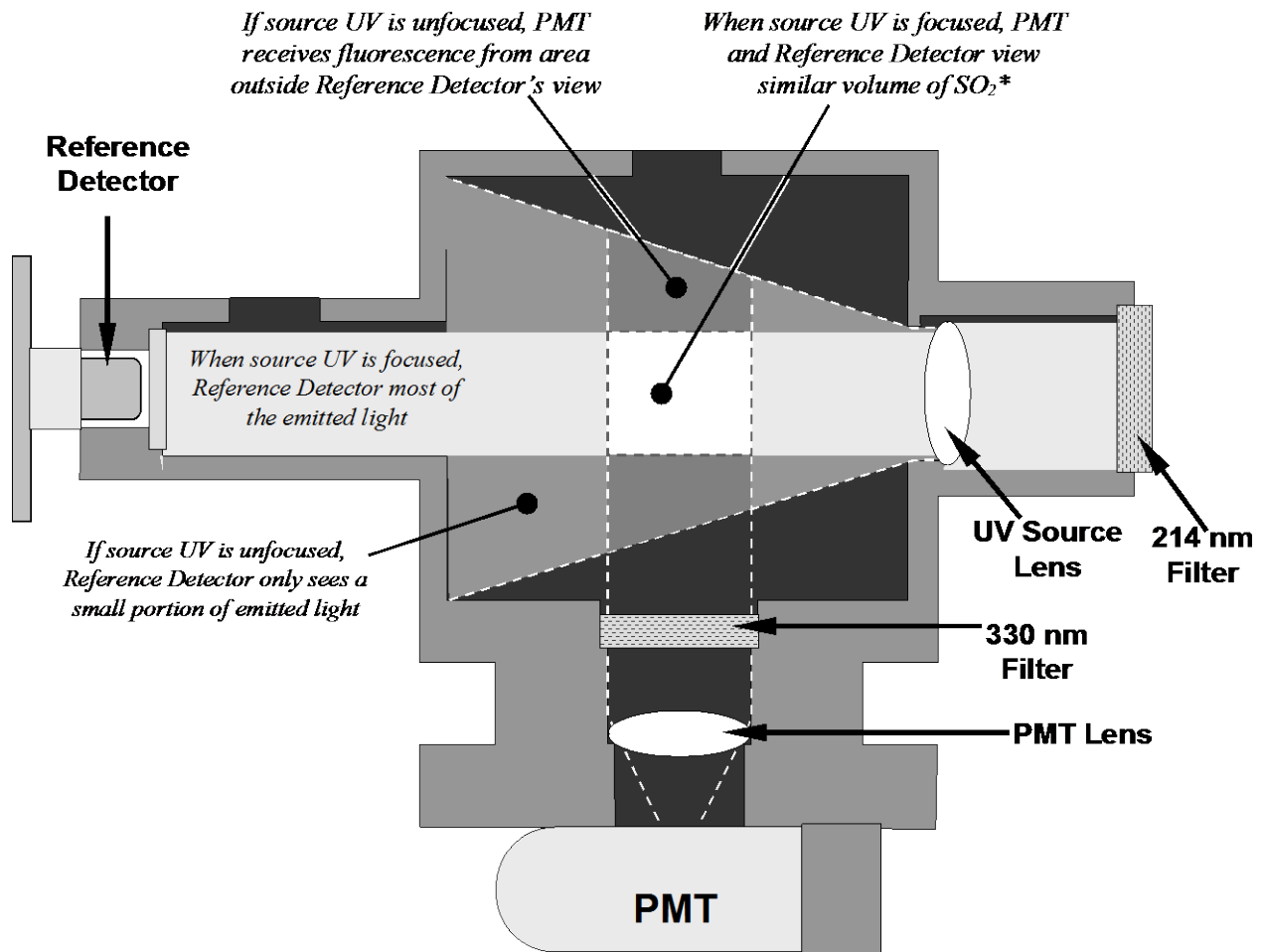


Figure 12-5: PMT Optical Filter Bandwidth

### 12.1.8. OPTICAL LENSES

Two optical lenses are used to focus and optimize the path of light through the sample chamber.



**Figure 12-6: Effects of Focusing Source UV in Sample Chamber**

A lens located between PMT and the sample chamber collects as much of the fluoresced UV created there as possible and focuses it on the most sensitive part of the PMT's photo cathode.

Another lens located between the excitation UV source lamp and the sample chamber collimates the light emitted by the lamp into a steady, circular beam and focuses that beam directly onto the reference detector. This allows the reference detector to accurately measure the effective intensity of the excitation UV by eliminating the effect of flickering inherent in the plasma arc that generates the light.

Ensure that all of the light emitted by the source lamp, passes through the 214 nm filter and not absorbed by the SO<sub>2</sub> reaches the reference detector. Conversely, this also makes sure that the volume of sample gas affected by the excitation beam is similar to the volume of fluorescing SO<sub>2</sub>\* being measured by the PMT, eliminating a possible source of measurement offset.

## 12.1.9. MEASUREMENT INTERFERENCES

It should be noted that the fluorescence method for detecting SO<sub>2</sub> is subject to interference from a number of sources. The T100 has been successfully tested for its ability to reject interference from most of these sources.

### 12.1.9.1. DIRECT INTERFERENCE

The most common source of interference is from other gases that fluoresce in a similar fashion to SO<sub>2</sub> when exposed to UV Light. The most significant of these is a class of hydrocarbons called poly-nuclear aromatics (PNA) of which xylene and naphthalene are two prominent examples. Nitrogen oxide fluoresces in a spectral range near to SO<sub>2</sub>. For critical applications where high levels of NO are expected an optional optical filter is available that improves the rejection of NO (contact Technical Support for more information).

- The T100 Analyzer has several methods for rejecting interference from these gases:
- A special scrubber (kicker) mechanism removes any PNA chemicals present in the sample gas before it reaches the sample chamber.
- The exact wavelength of light needed to excite a specific non-SO<sub>2</sub> fluorescing gas is removed by the source UV optical filter.
- The light given off by Nitrogen Oxide and many of the other fluorescing gases is outside of the bandwidth passed by the PMT optical filter.

### 12.1.9.2. UV ABSORPTION BY OZONE

Because ozone absorbs UV Light over a relatively broad spectrum it could cause a measurement offset by absorbing some of the UV given off by the decaying SO<sub>2</sub>\* in the sample chamber. The T100 prevents this from occurring by having a very short light path between the area where the SO<sub>2</sub>\* fluorescence occurs and the PMT detector. Because the light path is so short, the amount of O<sub>3</sub> needed to cause a noticeable effect would be much higher than could be reasonably expected in any application for which this instrument is intended.

### 12.1.9.3. DILUTION

Certain gases with higher viscosities can lower the flow rate through the critical flow orifice that controls the movement of sample gas through the analyzer reducing the amount of sample gas in the sample chamber and thus the amount of SO<sub>2</sub> available to react with the UV light. While this can be a significant problem for some analyzers, the design of the T100 is very tolerant of variations in sample gas flow rate and therefore does not suffer from this type of interference.

### 12.1.9.4. THIRD BODY QUENCHING

While the decay of SO<sub>2</sub>\* to SO<sub>2</sub> happens quickly, it is not instantaneous. Because it is not instantaneous it is possible for the extra energy possessed by the excited electron of the SO<sub>2</sub>\* molecule to be given off as kinetic energy during a collision with another molecule. This in effect heats the other molecule slightly and allows the excited electron to move into a lower energy orbit without emitting a photon.

The most significant interferents in this regard are nitrogen oxide (NO), carbon dioxide (CO<sub>2</sub>), water vapor (H<sub>2</sub>O) and molecular oxygen (O<sub>2</sub>). In ambient applications the quenching effect of these gases is negligible. For stack applications where the



concentrations of some or all of these may be very high, specific steps **MUST** be taken to remove them from the sample gas before it enters the analyzer.

#### 12.1.9.5. LIGHT POLLUTION

Because T100 measures light as a means of calculating the amount of SO<sub>2</sub> present, obviously stray light can be a significant interfering factor. The T100 removes this interference source in several ways.

- The sample chamber is designed to be completely light tight to light from sources other than the excitation UV source lamp.
- All pneumatic tubing leading into the sample chamber is completely opaque in order to prevent light from being piped into the chamber by the tubing walls.
- The optical filters discussed in Section 12.1.7; remove UV with wavelengths extraneous to the excitation and decay of SO<sub>2</sub>/SO<sub>2</sub>\*.
- Most importantly, during instrument calibration the difference between the value of the most recently recorded PMT offset (refer to Section 12.1.6) and the PMT output while measuring zero gas (calibration gas devoid of SO<sub>2</sub>) is recorded as the test function **OFFSET**. This **OFFSET** value is used during the calculation of the SO<sub>2</sub> concentration.

Since this offset is assumed to be due to stray light present in the sample chamber is also multiplied by the **SLOPE** and recorded as the function **STR. LGT**. Both **OFFSET** & **STR. LGT** are viewable via the front panel (refer to Section 4.1.1).

## 12.2. OXYGEN (O<sub>2</sub>) SENSOR PRINCIPLES OF OPERATION

The O<sub>2</sub> sensor applies paramagnetics to determine the concentration of oxygen in a sample gas drawn through the instrument.

### 12.2.1. PARAMAGNETIC MEASUREMENT OF O<sub>2</sub>

The oxygen sensor used in the T100 utilizes the fact that oxygen is attracted into strong magnetic field while most other gases are not, to obtain fast, accurate oxygen measurements.

The sensor's core is made up of two nitrogen filled glass spheres, which are mounted on a rotating suspension within a magnetic field (refer to Figure 12-7). A mirror is mounted centrally on the suspension and light is shone onto the mirror that reflects the light onto a pair of photocells. The signal generated by the photocells is passed to a feedback loop, which outputs a current to a wire winding (in effect, a small DC electric motor) mounted on the suspended mirror.

Oxygen from the sample stream is attracted into the magnetic field displacing the nitrogen filled spheres and causing the suspended mirror to rotate. Therefore, the amount of light reflected onto the photocells and therefore the output levels of the photocells. The feedback loop increases the amount of current fed into the winding in order to move the mirror back into its original position. The more O<sub>2</sub> present, the more the mirror moves and the more current is fed into the winding by the feedback control loop.

A sensor measures the amount of current generated by the feedback control loop which is directly proportional to the concentration of oxygen within the sample gas mixture.

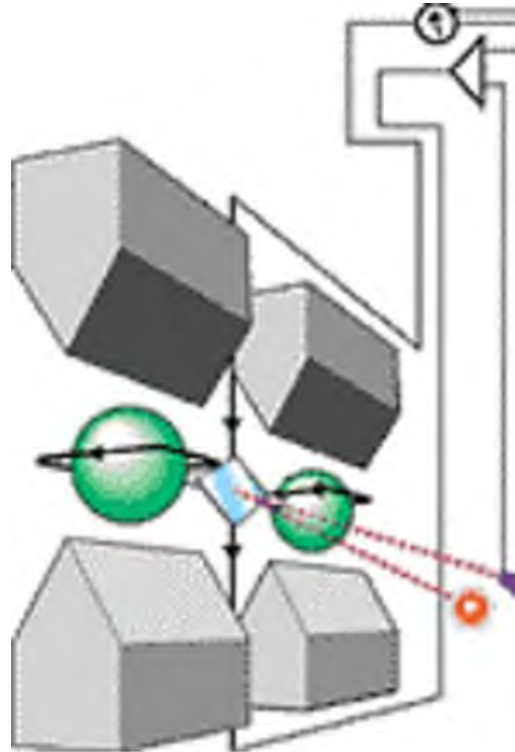


Figure 12-7: Oxygen Sensor - Principles of Operation

### 12.2.2. O<sub>2</sub> SENSOR OPERATION WITHIN THE T100 ANALYZER

The oxygen sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel display, just like the functions for SO<sub>2</sub>.

- The O<sub>2</sub> concentration is displayed below the SO<sub>2</sub> concentration.
- Test functions for O<sub>2</sub> slope and offset are viewable from the front panel along with the other test functions of the analyzer.
- O<sub>2</sub> sensor calibration is performed via the front panel **CAL** function and is performed in a nearly identical manner as the standard SO<sub>2</sub> calibration. Refer to Section 9.10.1 for more details.
- Stability of the O<sub>2</sub> sensor can be viewed via the front panel (refer to Section 9.10.1.3).

The O<sub>2</sub> concentration range is 0-100% (user selectable) with 0.1% precision and accuracy.

The temperature of the O<sub>2</sub> sensor is maintained at a constant 50°C by means of a PID loop and can be viewed on the front panel as test function O<sub>2</sub> TEMP.

The O<sub>2</sub> sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

## 12.3. CARBON DIOXIDE (CO<sub>2</sub>) SENSOR PRINCIPLES OF OPERATION

The CO<sub>2</sub> sensor probe measures the concentration of carbon dioxide in the sample gas; a Logic PCA conditions the probe output and issues a 0-5 VDC signal to the analyzer's CPU, which computes the CO<sub>2</sub> concentration by scaling the values of the CO<sub>2</sub>\_SLOPE and CO<sub>2</sub>\_OFFSET recorded during calibration

The CO<sub>2</sub> sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

### 12.3.1. NDIR MEASUREMENT OF CO<sub>2</sub>

The optional CO<sub>2</sub> sensor is a silicon based Non-Dispersive Infrared (NDIR) sensor. It uses a single-beam, dual wavelength measurement method.

An infrared source at one end of the measurement chamber emits IR radiation into the sensor's measurement chamber where light at the 4.3 μm wavelength is partially absorbed by any CO<sub>2</sub> present. A special light filter called a Fabry-Perot Interferometer (FPI) is electronically tuned so that only light at the absorption wavelength of CO<sub>2</sub> is allowed to pass and be detected by the sensor's IR detector.

A reference measurement is made by electronically shifting the filter band pass wavelength so that no IR at the CO<sub>2</sub> absorption wavelength is let through.

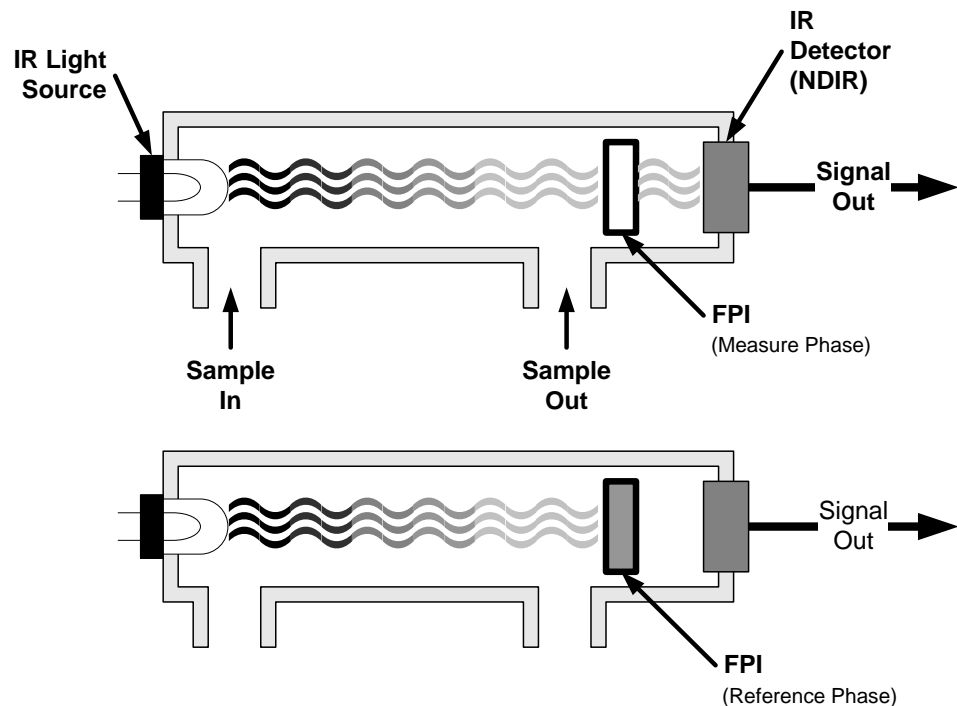


Figure 12-8: CO<sub>2</sub> Sensor Principles of Operation

The sensor computes the ratio between the reference signal and the measurement signal to determine the degree of light absorbed by CO<sub>2</sub> present in the sensor chamber. This dual wavelength method the CO<sub>2</sub> measurement allows the instrument to compensate for ancillary effects like sensor aging and contamination.

### 12.3.2. CO<sub>2</sub> OPERATION WITHIN THE T100 ANALYZER

The CO<sub>2</sub> sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel display, just like the functions for SO<sub>2</sub>.

- The CO<sub>2</sub> concentration is displayed below the SO<sub>2</sub> concentration.
- Test functions for CO<sub>2</sub> slope and offset are viewable from the front panel along with the other test functions of the analyzer.
- CO<sub>2</sub> sensor calibration is performed via the front panel **CAL** function and is performed in a nearly identical manner as the standard SO<sub>2</sub> calibration.
- Stability of the CO<sub>2</sub> sensor can be viewed via the front panel (refer to Section 9.10.2.3).

Refer to Section 3.4.4.3 for information on calibrating the CO<sub>2</sub>.

### 12.3.3. ELECTRONIC OPERATION OF THE CO<sub>2</sub> SENSOR

The CO<sub>2</sub> PCA, which is mounted to the rear side of the Relay Board Mounting Bracket, controls the CO<sub>2</sub> sensor. It converts the sensor's digital output to an analog voltage that is measured with the motherboard and draws 12 VDC from the analyzer via the relay card from which converts to fit the power needs of the probe and its own onboard logic. It outputs a 0-5 VDC analog signal to the analyzer's CPU via the motherboard that corresponds to the concentration of CO<sub>2</sub> measured by the probe.

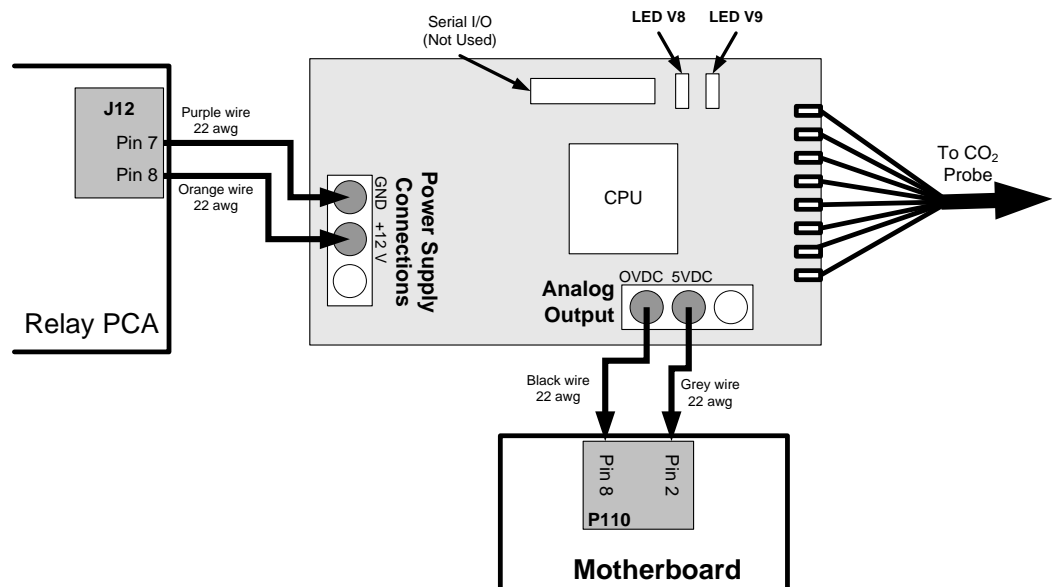


Figure 12-9: CO<sub>2</sub> Sensor Option PCA Layout and Electronic Connections

## 12.4. PNEUMATIC OPERATION

### IMPORTANT

#### IMPACT ON READINGS OR DATA

It is important that the sample airflow system is leak-tight and not pressurized over ambient pressure. Regular leak checks should be performed on the analyzer as described in the maintenance schedule, Table 10-1. Procedures for correctly performing leak checks can be found in Section 10.3.6.

### IMPORTANT

#### Relative Pressure versus Absolute Pressure

In this manual vacuum readings are given in inches of mercury absolute pressure (in-Hg-A), i.e. indicate an absolute pressure referenced against zero (a perfect vacuum).

### 12.4.1. SAMPLE GAS FLOW

The Flow of gas through the T100 UV Fluorescence SO<sub>2</sub> Analyzer is created by a small internal pump that pulls air through the instrument.

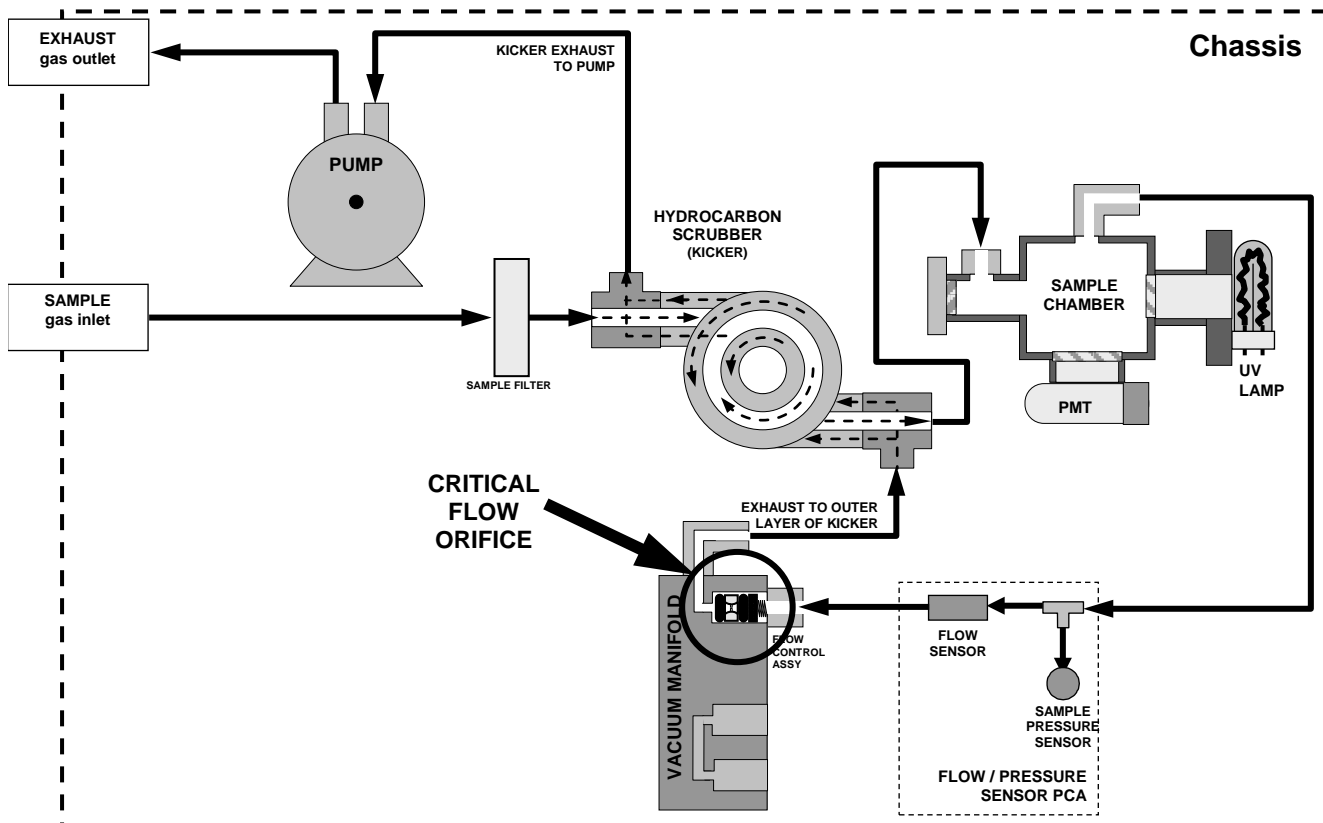


Figure 12-10: Gas Flow and Location of Critical Flow Orifice

## 12.4.2. FLOW RATE CONTROL

The T100 uses a special flow control assembly located in the exhaust vacuum manifold (refer to Figure 12-10) to maintain a constant flow rate of the sample gas through the instrument. This assembly consists of:

- A critical flow orifice.
- Two o-rings: Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice.
- A spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

### 12.4.2.1. CRITICAL FLOW ORIFICE

The most important component of this flow control assembly is the critical flow orifice.

Critical flow orifices are a simple way to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. Restricting the flow of gas through the orifice creates a pressure differential. This pressure differential combined with the action of the analyzer's pump draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows through the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1 the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.

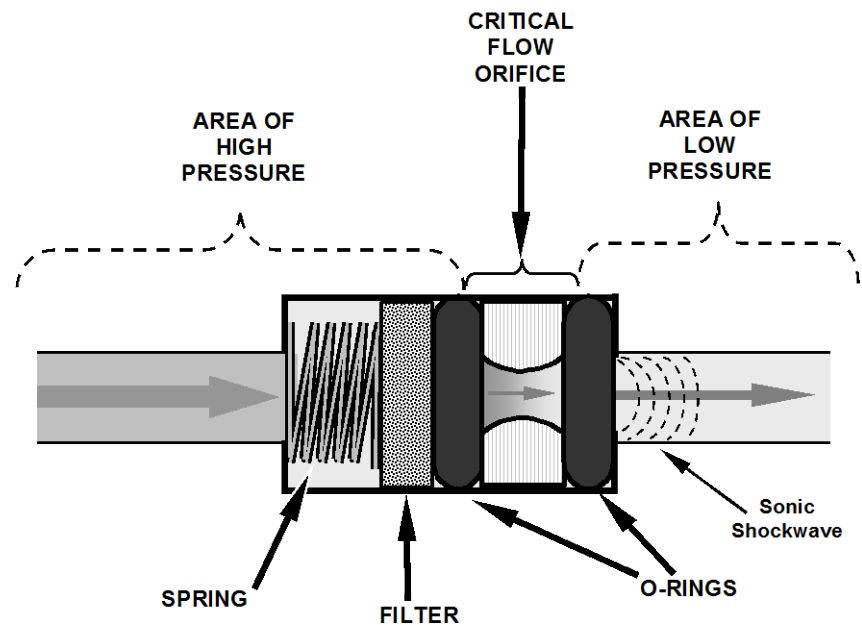


Figure 12-11: Flow Control Assembly & Critical Flow Orifice

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. Because the flow rate of gas through the orifice is only related to the minimum 2:1 pressure differential and not absolute pressure the flow rate of the gas is also unaffected by degradations in pump efficiency due to age.

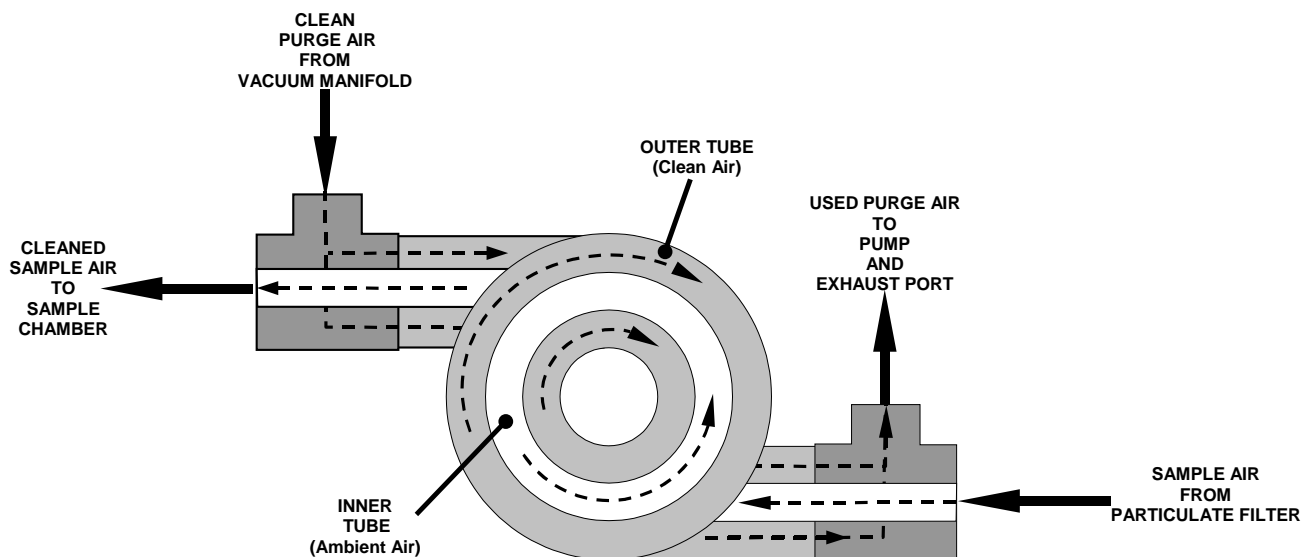
The critical flow orifice used in the T100 is designed to provide a flow rate of 650 cm<sup>3</sup>/min.

#### 12.4.2.2. SAMPLE PARTICULATE FILTER

To remove particles in the sample gas, the analyzer is equipped with a Teflon membrane filter of 47 mm diameter (also referred to as the sample filter) with a 1 μm or 5 μm pore size. The filter is accessible through the front panel, which folds down, and should be changed according to the suggested maintenance schedule listed in Table 10-1.

#### 12.4.3. HYDROCARBON SCRUBBER (KICKER)

It is very important to ensure that the air supplied sample chamber is clear of hydrocarbons. To accomplish this task the T100 uses a single tube permeation scrubber. The scrubber consists of a single tube of a specialized plastic that absorbs hydrocarbons very well. This tube is located within outer flexible plastic tube shell. As gas flows through the inner tube, hydrocarbons are absorbed into the membrane walls and transported through the membrane wall and into the hydrocarbon free, purge gas flowing through the outer tube. This process is driven by the hydrocarbon concentration gradient between the inner and outer of the tubes.



**Figure 12-12: T100 Hydrocarbon Scrubber (Kicker)**

In the T100 some of the cleaned air from the inner tube is returned to be used as the purge gas in the outer tube (refer to Figure 12-12). This means that when the analyzer is first started, the concentration gradient between the inner and outer tubes is not very large and the scrubber's efficiency is relatively low. When the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the gradient to become large enough for the scrubber to adequately remove hydrocarbons from the sample air.

## 12.4.4. PNEUMATIC SENSORS

The T100 uses two pneumatic sensors to verify gas streams. These sensors are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board. The flow simultaneously enters the sample pressure sensor and the flow sensor from the outlet of the reaction cell.

### 12.4.4.1. SAMPLE PRESSURE SENSOR

An absolute pressure transducer plumbed to the input of the analyzer's sample chamber is used to measure the pressure of the sample gas before it enters the chamber. This upstream measurement is used to validate the critical flow condition (2:1 pressure ratio) through the instrument's critical flow orifice (refer to Section 12.4.2). Also, if the Temperature/Pressure Compensation (TPC) feature is turned on (refer to Section 12.7.3), the output of this sensor is also used to supply pressure data for that calculation.

The actual pressure measurement is viewable through the analyzer's front panel display as the test function **PRESS**.

### 12.4.4.2. SAMPLE FLOW SENSOR

A thermal-mass flow sensor is used to measure the sample flow through the analyzer. This sensor is also mounted on the pneumatic pressure/flow sensor board upstream of the sample chamber. The flow rate is monitored by the CRT which issues a warning message (**SAMP FLOW WARN**) if the flow rate is too high or too low.

The flow rate of the sample gas is viewable via the front panel as the **SAMP FL** test function.



## 12.5. ELECTRONIC OPERATION

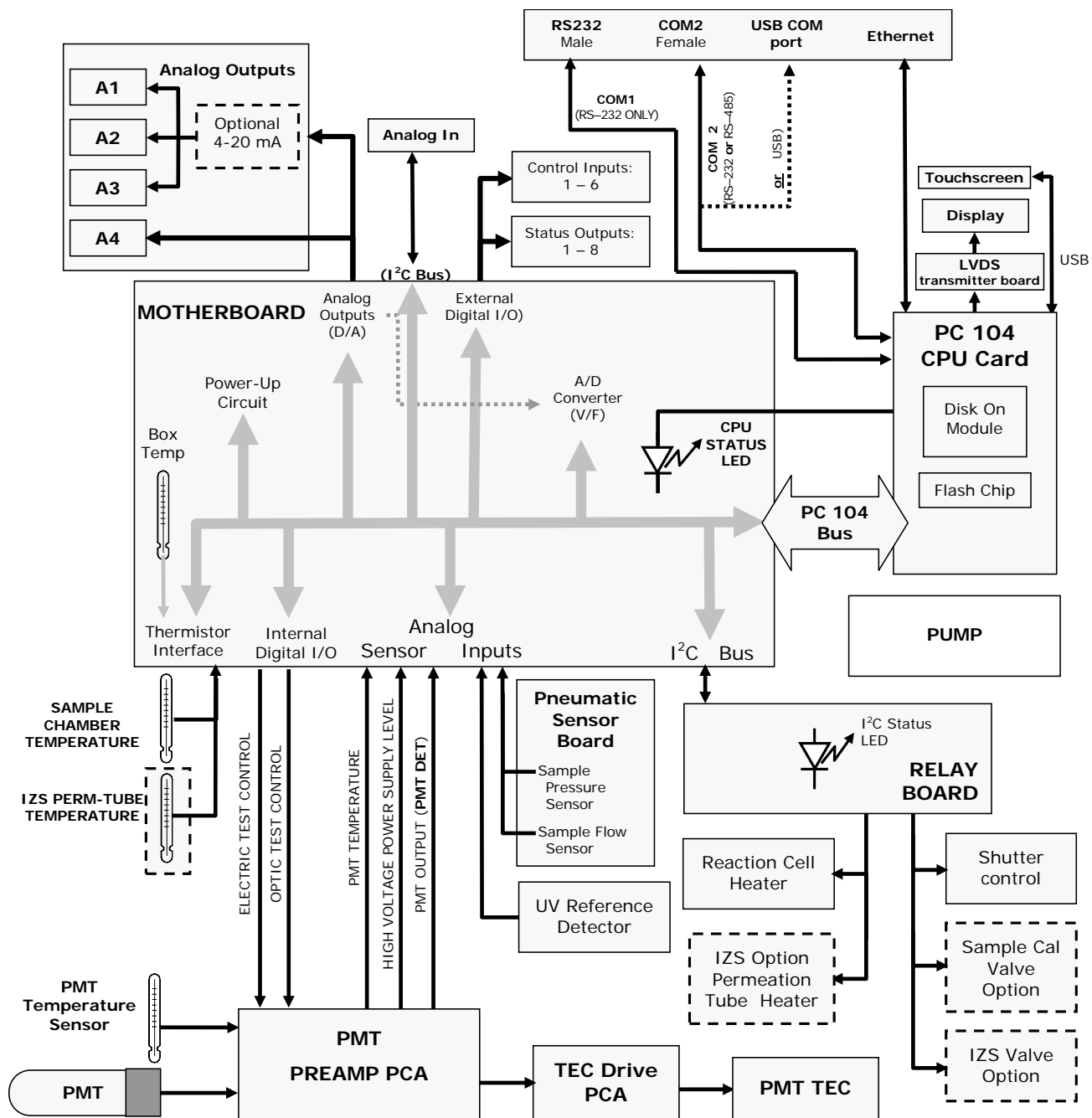


Figure 12-13: T100 Electronic Block Diagram

The core of the analyzer is a microcomputer 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 through a separate printed circuit assembly to which the CPU is mounted: the motherboard.

The motherboard is directly mounted to the rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Concentration data of the T100 are generated by the Photo Multiplier Tube (PMT), which produces an analog current signal corresponding to the brightness of the fluorescence reaction in the sample chamber. This current signal is amplified to a DC voltage signal (front panel test parameter **PMT**) by a PMT preamplifier printed circuit assembly (located on top of the sensor housing). **PMT** is converted to digital data by a bi-polar, analog-to-digital converter, located on the motherboard.

In addition to the PMT signal, a variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the SO<sub>2</sub> concentration calculation (e.g. pressure and temperature reading used by the temperature/pressure compensation feature) and as trigger events for certain warning messages and control commands issued by the CPU. They are stored in the CPU's memory and, in most cases, can be viewed through the front panel display.

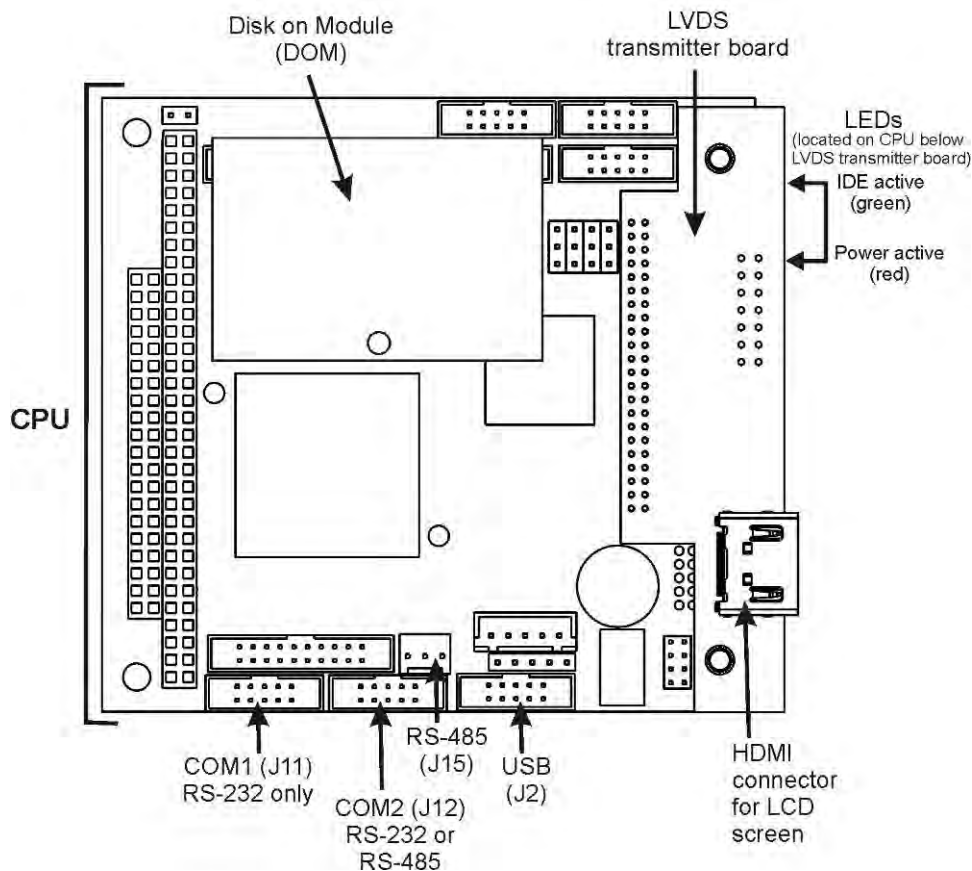
The CPU communicates with the user and the outside world in a variety of ways:

- Through the analyzer's front panel LCD touch-screen interface
- RS-232 and RS-485 serial I/O channels
- Various analog voltage and current outputs
- Several digital I/O channels
- Ethernet

Finally, the CPU issues commands (also over the I<sup>2</sup>C bus) to a series of relays and switches located on a separate printed circuit assembly, the relay board (located in the rear of the chassis on its own mounting bracket) to control the function of key electromechanical devices such as valves and heaters.

### 12.5.1. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex 86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification.



**Figure 12-14: CPU Board Annotated**

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

#### 12.5.1.1. DISK ON MODULE (DOM)

The DOM is a 44-pin IDE flash chip with storage capacity to 256 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS). Embedded in the DOM is a flash chip.

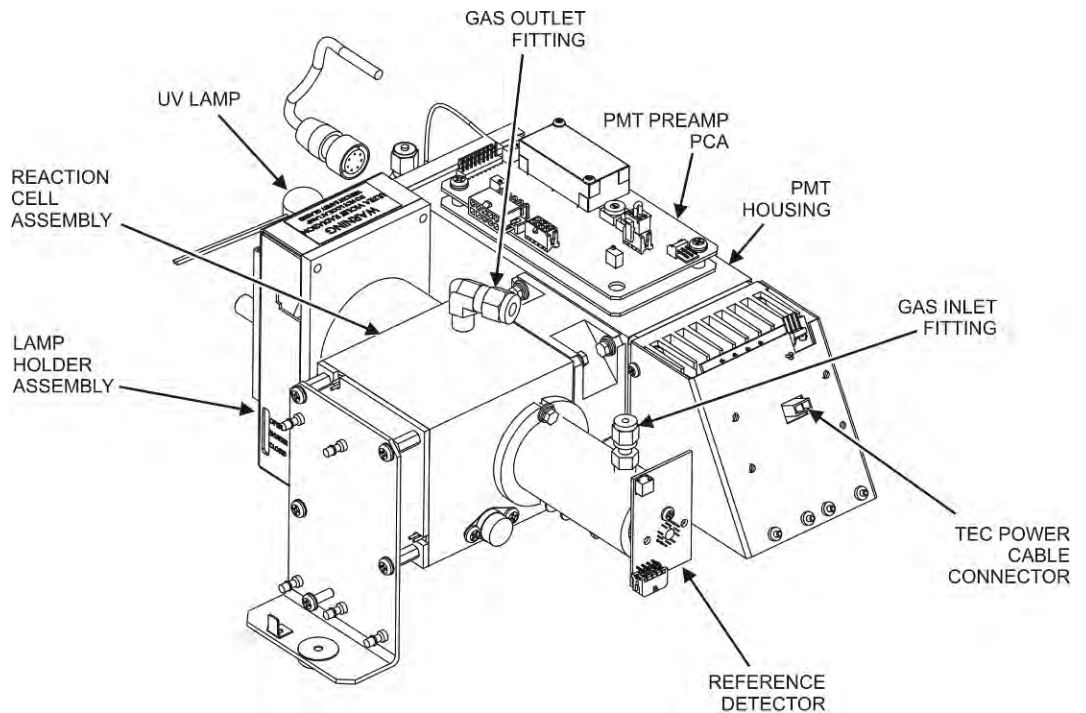
#### 12.5.1.2. FLASH CHIP

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data onto a less heavily accessed chip significantly decreases the chance of data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring that the unit be recalibrated.

## 12.5.2. SENSOR MODULE

Electronically, the T100 sensor module is a group of components that: create the UV light that initiates the fluorescence reaction between SO<sub>2</sub> and O<sub>3</sub>; sense the intensity of that fluorescence; generate various electronic signals needed by the analyzer to determine the SO<sub>2</sub> concentration of the sample gas (refer to Section 12.1.1), and sense and control key environmental conditions such as the temperature of the sample gas and the PMT.



**Figure 12-15: T100 Sensor Module**

These components are divided into two significant subassemblies: the sample chamber and the PMT assembly.

Figure 12-16 shows an exploded view of the sample chamber assembly

Figure 12-17 shows an exploded view of the PMT Assembly

### 12.5.2.1. SAMPLE CHAMBER

The main electronic components of the sample chamber are the reference detector (refer to Section 12.1.4); the UV Lamp (refer to Section 12.1.3) and its electronically operated shutter (refer to Section 12.1.6); and the sample chamber heating circuit.

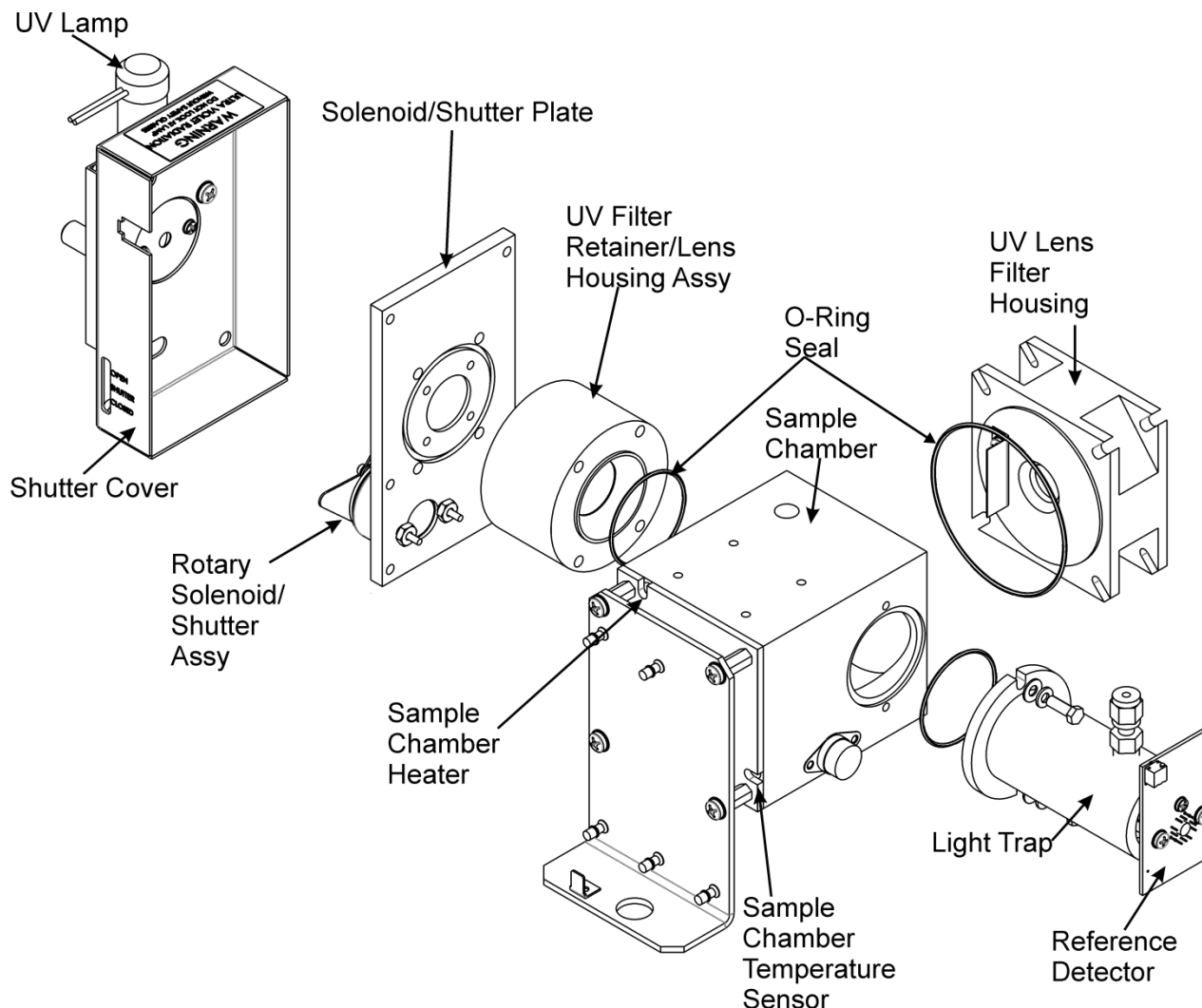


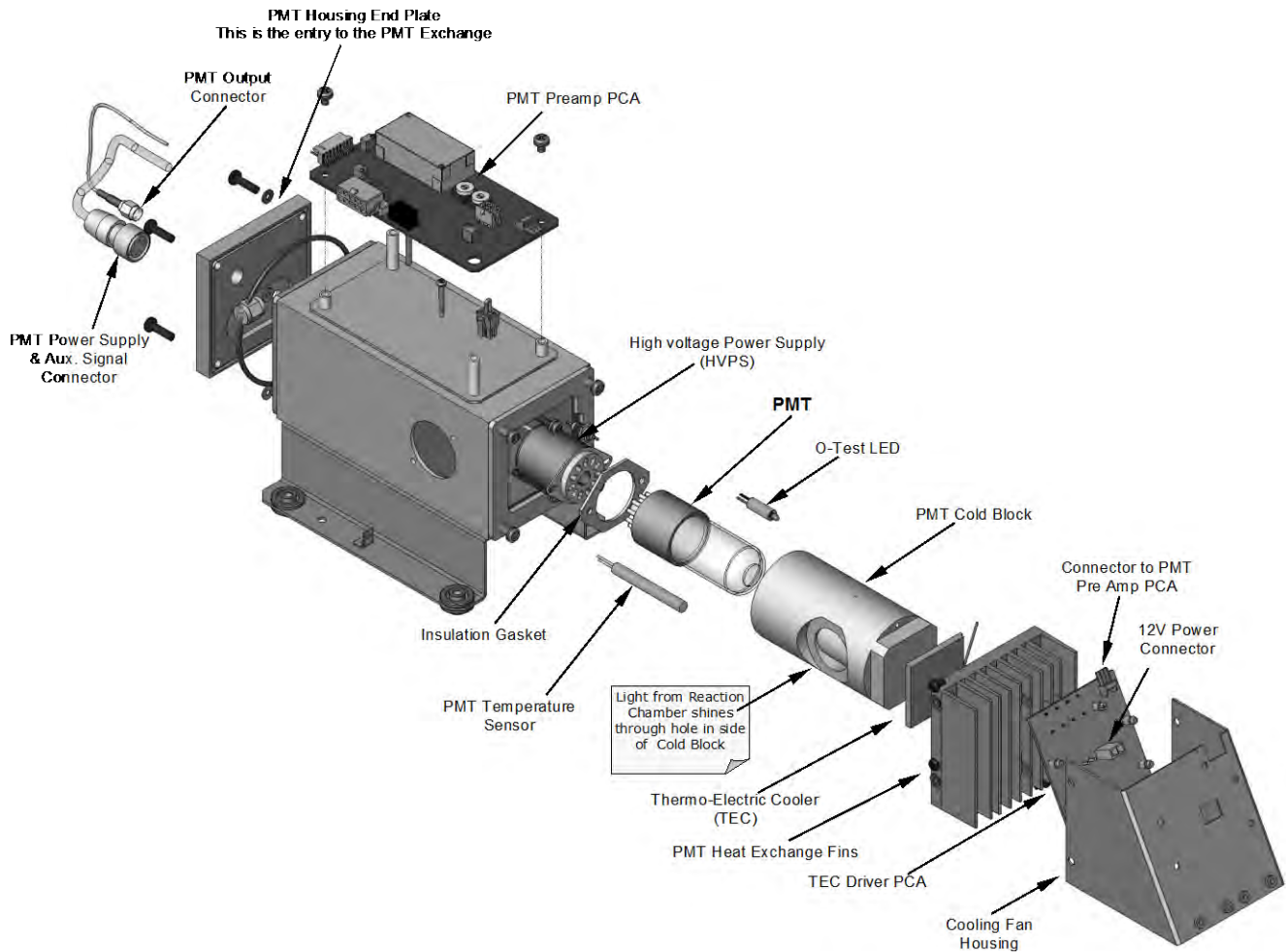
Figure 12-16: T100 Sample Chamber

### 12.5.2.2. SAMPLE CHAMBER HEATING CIRCUIT

In order to reduce temperature effects, the sample chamber is maintained at a constant 50°C, just above the high end of the instrument's operation temperature range. Two AC heaters, one embedded into the top of the sample chamber, the other embedded directly below the reference detector's light trap, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board. A thermistor, also embedded in the bottom of the sample chamber, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard.

### 12.5.3. PHOTO MULTIPLIER TUBE (PMT)

The T100 uses a photo multiplier tube (PMT) to detect the amount of fluorescence created by the SO<sub>2</sub> and O<sub>3</sub> reaction in the sample chamber.



**Figure 12-17: PMT Housing Assembly**

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes. The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased number of electrons emitted from one end of electron multiplier is collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.

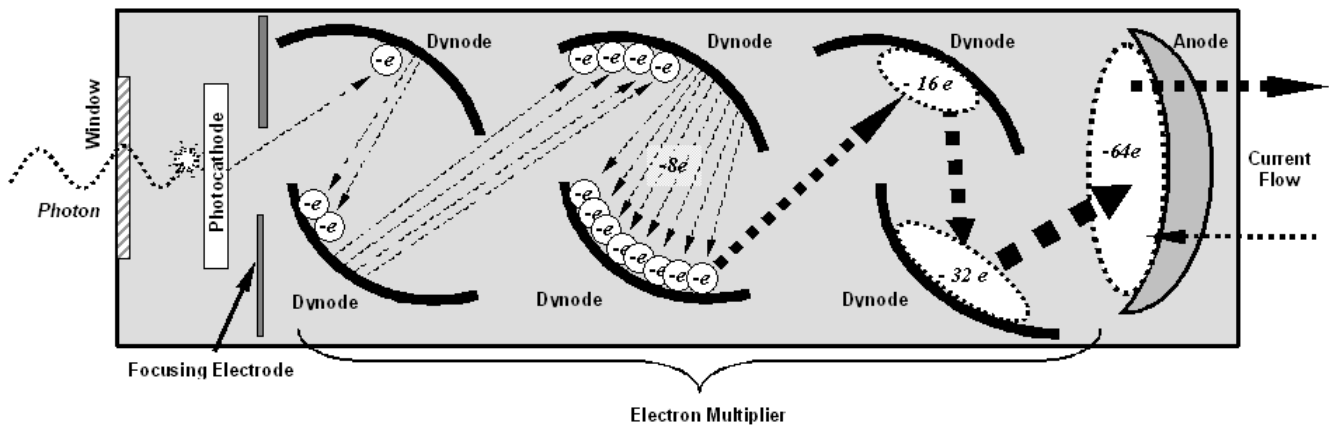


Figure 12-18: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater is the number of electrons emitted from each dynode of the electron multiplier, making the PMT more sensitive and responsive to small variations in light intensity but also more noisy (dark noise). The gain voltage of the PMT used in the T100 is usually set between 450 V and 800 V. This parameter is viewable through the front panel as test function **HVPS** (refer to Section 4.1.1). For information on when and how to set this voltage, refer to Section 11.7.2.8.

The PMT is housed inside the PMT module assembly (refer to Figure 12-15 and Figure 12-17). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument's optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the Thermo-Electric Cooler (TEC).

### 12.5.4. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer the PMT is, the noisier its signal becomes until the noise renders the concentration signal useless. To alleviate this problem a special cooling system exists that maintains the PMT temperature at a stable, low level.

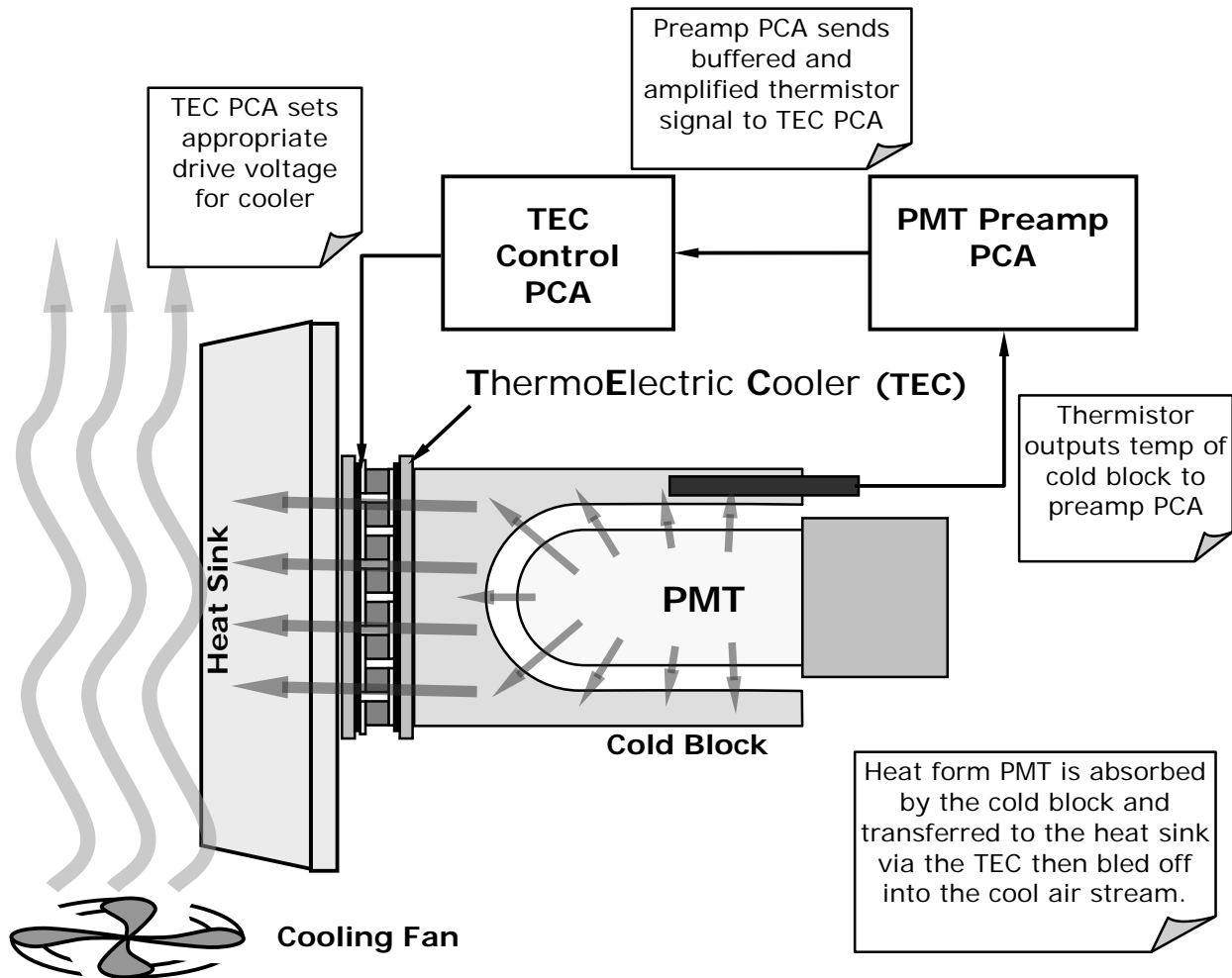


Figure 12-19: PMT Cooling System

#### 12.5.4.1. THERMOELECTRIC COOLER (TEC)

The core of the T100 PMT cooling system is a solid state heat pump called a thermoelectric cooler (TEC). Thermoelectric coolers transfer heat from a one side of a special set of semiconductor junctions to the other when a DC current is applied. The heat is pumped at a rate proportional to the amount of current applied. In the T100 the TEC is physically attached to a cold block that absorbs heat directly from the PMT and a heat sink that is cooled by moving air (refer to Figure 12-19). A Thermocouple embedded into the cold block generates an analog voltage corresponding to the current temperature of the PMT. The PMT Preamp PCA conditions and amplifies this signal then passes it on to the TEC Control PCA.



#### 12.5.4.2. TEC CONTROL BOARD

The TEC control printed circuit assembly is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (refer to Section 12.5.5), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power. Four test points are also located at the top of this assembly. For the definitions and acceptable signal levels of these test points refer to Section 11.1.2.

#### 12.5.5. PMT PREAMPLIFIER

The PMT preamplifier board amplifies the PMT signal into a useable analog voltage that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the SO<sub>2</sub> concentration of the gas in the sample chamber.

The output signal of the PMT is controlled by two different adjustments. First, the voltage across the electron multiplier array of the PMT is adjusted with a set of two hexadecimal switches. Adjusting this voltage directly affects the HVPS voltage and, hence, the signal from the PMT. Secondly, the gain of the amplified signal can further be adjusted through a potentiometer. These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. Refer to Section 11.7.2.8 for this hardware calibration.

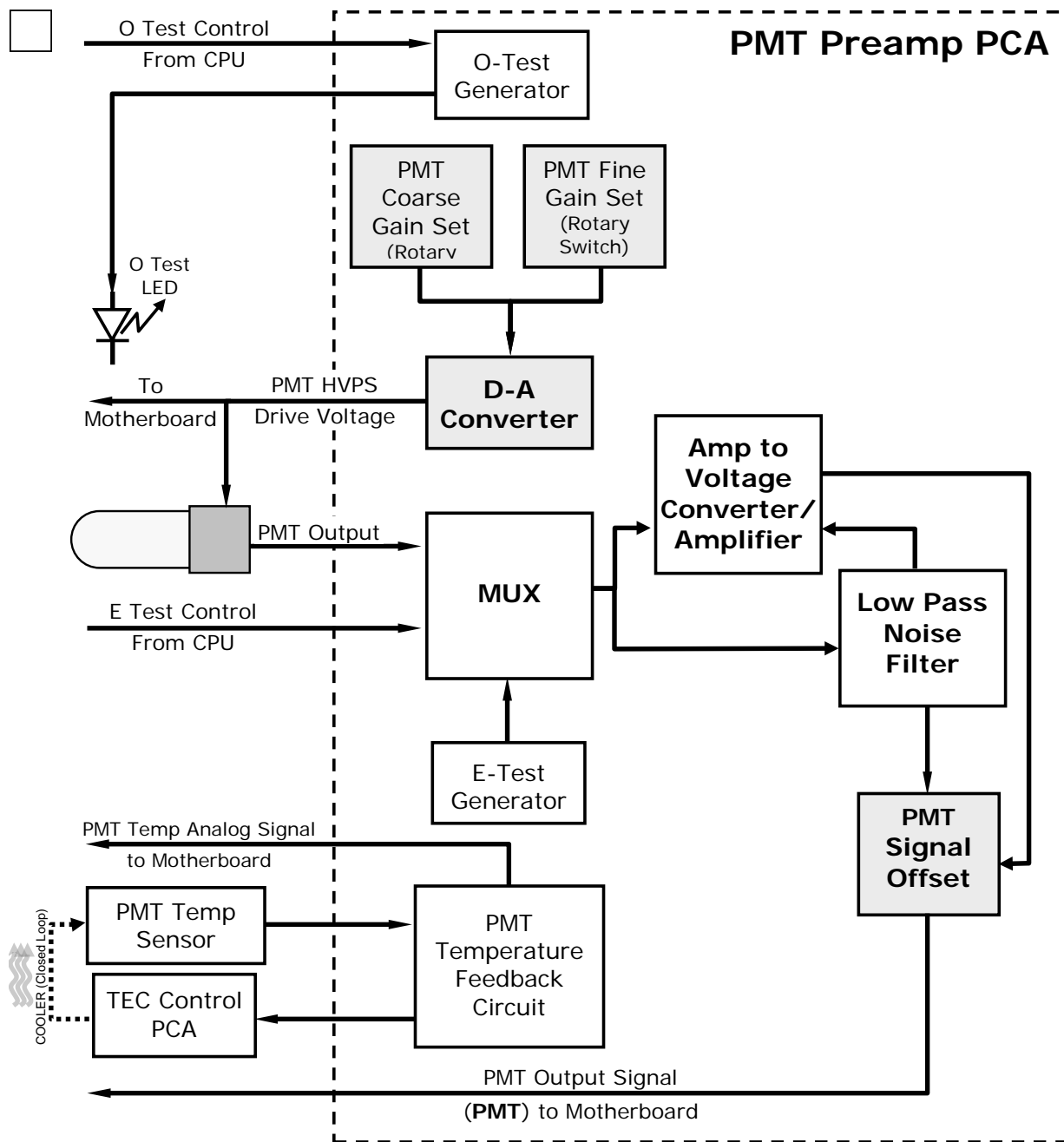


Figure 12-20: PMT Preamp Block Diagram

The PMT temperature control loop maintains the PMT temperature around 7° C and can be viewed as test function **PMT TEMP** on the front panel (refer to Section 4.1.1).

The electrical test (**ETEST**) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector's actual signal, it is possible to test most of the signal handling and conditioning circuitry on the PMT preamplifier board. Refer to Section 5.9.5 for instructions on performing this test.

The optical test (**OTEST**) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer,

the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. Refer to Section 5.9.4 for instructions on performing this test.

### 12.5.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the T100 are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 11.6.15 on how to test this assembly. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel. Refer to Section 5.4.3.2 for instructions on performing this test.

### 12.5.7. RELAY BOARD

The relay board is the central switching unit of the analyzer. It contains power relays, status LEDs for all heated zones and valves, as well as valve drivers, thermocouple amplifiers, power distribution connectors and the two switching power supplies of the analyzer. The relay board communicates with the motherboard over the I<sup>2</sup>C bus and is the main board for trouble-shooting power problems of any kind.

#### 12.5.7.1. HEATER CONTROL

The T100 uses a variety of heaters for its individual components. All heaters are AC powered and can be configured for 100/120 VAC or 220/230VAC at 50-60 Hz.

The two sample chamber heaters are electronically connected in parallel for analyzers at 100/120 VAC line power and in series for units configured for 220/230 VAC. One configuration plug on the relay board determines the power configuration for the entire analyzer.

On units with IZS options installed, an additional set of AC heaters is attached to the IZS permeation tube. Some special T100 models may have other, non-standard heating zones installed, such as a dilution manifold.

#### 12.5.7.2. VALVE CONTROL

The relay board also hosts two valve driver chips, each of which can drive up four valves. In its basic configuration the T100 requires no valve control to operate. However, on units with either the zero/span valve or the IZS option installed, the valve control is used. Manifold valves, which may also be present in certain special versions of the analyzer, would also use valve control.

## 12.5.7.3. STATUS LEDs &amp; WATCH DOG CIRCUITRY

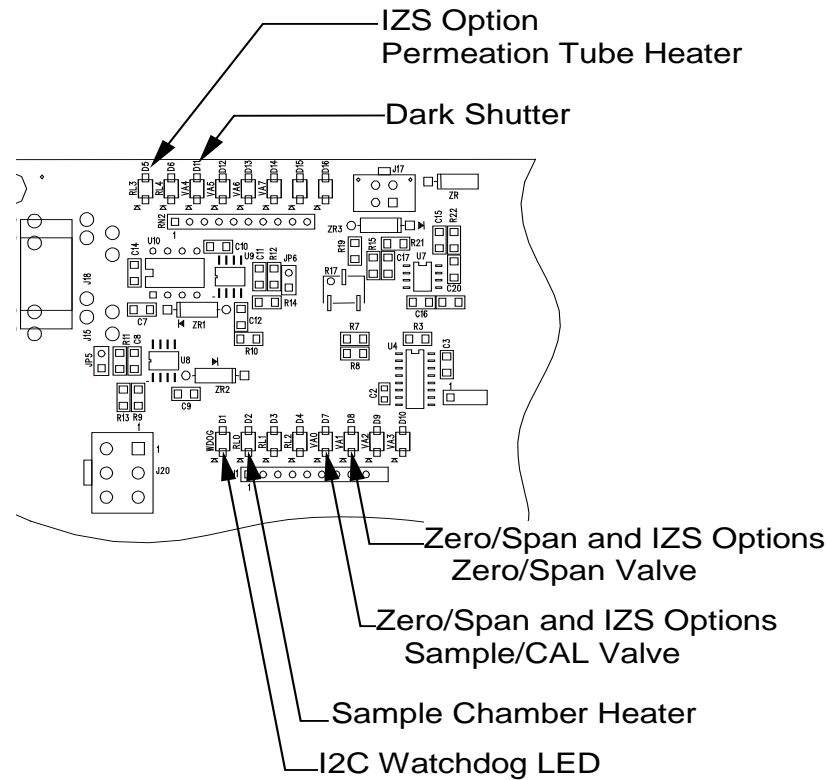


Figure 12-21: Relay Board Status LED Locations

Thirteen LEDs are located on the analyzer's relay board to indicate the status of the analyzer's heating zones and valves as well as a general operating watchdog indicator. Table 12-1 shows the state of these LEDs and their respective functionality.

Table 12-1: Relay Board Status LED's

LED	COLOR	FUNCTION	STATUS WHEN LIT	STATUS WHEN UNLIT
D1	RED	Watchdog circuit	Cycles On/Off every 3 seconds under control of the CPU.	
D2	YELLOW	Sample chamber (RCELL) heater	HEATING	NOT HEATING
D3, D4	YELLOW	Unused	N/A	N/A
D5	YELLOW	IZS heater (option)	HEATING	NOT HEATING
D6	YELLOW	Unused	N/A	N/A
D7	GREEN	Zero / Span Valve	Valve open to Span Gas path	Valve open to Zero Gas (normal state)
D8	GREEN	Sample / Cal Valve	Valve open to calibration gas path	Valve open to sample gas inlet on rear panel (normal state)
D9, D10	GREEN	Unused	N/A	N/A
D11	GREEN	UV Lamp Shutter	Shutter open	Shutter closed
D12-14	GREEN	Unused	N/A	N/A

As a safety measure, special circuitry on the relay board watches the status of LED D1. Should this LED ever stay **ON** or **OFF** for 30 seconds, indicating that the CPU or I<sup>2</sup>C bus has stopped functioning, the Watchdog Circuit will automatically shut off all valves as well as turn off the UV Source(s) and all heaters. The Sample pump will still be running.

## 12.5.8. MOTHERBOARD

This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I<sup>2</sup>C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

### 12.5.8.1. A TO D CONVERSION

Analog signals, such as the voltages received from the analyzer's various sensors, are converted into digital signals that the CPU can understand and manipulate by the Analog to Digital converter (A/D). Under the control of the CPU, this functional block selects a particular signal input and then converts the selected voltage into a digital word.

The A/D consists of a Voltage-to-Frequency (V-F) converter, a Programmable Logic Device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time period, and sends the result of that count, in the form of a binary number, to the CPU.

The A/D can be configured for several different input modes and ranges but it is used in uni-polar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from -0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions. Refer to Section 5.9.3.6 for instructions on performing this calibration.

### 12.5.8.2. SENSOR INPUTS

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.

**PMT DETECTOR OUTPUT:** This signal, output by the PMT preamp PCA, is used in the computation of the SO<sub>2</sub>, CO<sub>2</sub> and O<sub>2</sub> concentrations displayed in the front panel display screen and output through the instrument's analog outputs and **COMM** ports.

**PMT HIGH VOLTAGE POWER SUPPLY LEVEL:** This input is based on the drive voltage output by the PMT preamp board to the PMT's high voltage power supply (HVPS). It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS and stored in the instrument's memory as the test function **HVPS**. **HVPS** is viewable as a test function (refer to Section 4.1.1) through the analyzer's front panel.

**PMT TEMPERATURE:** This signal is the output of the thermistor attached to the PMT cold block amplified by the PMT temperature feedback circuit on the PMT preamp board. It is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

This measurement is stored in the analyzer. Memory as the test function **PMT TEMP** and is viewable as a test function (refer to Section 4.1.1) through the analyzer's front panel.

**SAMPLE GAS PRESSURE SENSOR:** This sensor measures the gas pressure at the exit of the sample chamber.

**SAMPLE FLOW SENSOR:** This sensor measure the flow rate of the sample gas as it exits the sample chamber.

### 12.5.8.3. THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the analyzer. They are as follows:

**SAMPLE CHAMBER TEMPERATURE SENSOR:** The source of this signal is a thermistor imbedded in the of the sample chamber block. It measures the temperature of the sample gas in the chamber. The data are used by the CPU to control sample chamber the heating circuit and as part of the SO<sub>2</sub>, calculations when the instrument's Temperature/Pressure Compensation feature is enabled.

This measurement is stored in the analyzer. Memory as the Test Function **RCEL TEMP** and is viewable as a test function (refer to Section 4.1.1) in the analyzer's front panel display.

**IZS OPTION PERMEATION TUBE TEMPERATURE SENSOR:** This thermistor, attached to the permeation tube in the IZS option, reports the current temperature of that tube to the CPU as part of control loop that keeps the tube at a constant temperature.

**BOX TEMPERATURE SENSOR:** A thermistor is attached to the motherboard. It measures the analyzer's internal temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes through the front panel display. This measurement is stored in the analyzer's memory as the test function **BOX TEMP** and is viewable as a test function (refer to Section 4.1.1) in the analyzer's front panel display.

### 12.5.9. ANALOG OUTPUTS

The analyzer comes equipped with four Analog Outputs: **A1**, **A2**, **A3** and a fourth that is a spare.

**A1 and A2 Outputs:** The first two, **A1** and **A2** are normally set up to operate in parallel so that the same data can be sent to two different recording devices. While the names imply that one should be used for sending data to a chart recorder and the other for interfacing with a data logger, either can be used for both applications.

Both of these channels output a signal that is proportional to the SO<sub>2</sub> concentration of the sample gas. The **A1** and **A2** outputs can be slaved together or set up to operated independently. A variety of scaling factors are available; refer to Section 5.4 for information on setting the range type and Section 5.9.3 for adjusting the electronic scaling factors of these output channels

**Test Output:** The third analog output, labeled **A3** is special. It can be set by the user (refer to Section 5.9.9) to carry the signal level of any one of the parameters accessible through the **TEST** menu of the unit's software.

In its standard configuration, the analyzer comes with all four of these channels set up to output a DC voltage. However, 4-20mA current loop drivers can be purchased for the first two of these outputs (**A1** and **A2**). Refer to Sections 1.4 (Option 41), 3.3.1.3 and 5.9.3.5.

**Output Loop-back:** All three of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures (refer to Section 5.9.3.2).

## 12.5.10. EXTERNAL DIGITAL I/O

This External Digital I/O performs two functions.

**STATUS OUTPUTS:** Logic-Level voltages are output through an optically isolated 8-pin connector located on the rear panel of the analyzer. These outputs convey good/bad and on/off information about certain analyzer conditions. They can be used to interface with certain types of programmable devices (refer to Section 8.1.1).

**CONTROL INPUTS:** By applying +5VDC power supplied from an external source such as a PLC or Data logger (refer to Section 8.1.2), Zero and Span calibrations can be initiated by contact closures on the rear panel.

## 12.5.11. I<sup>2</sup>C DATA BUS

I<sup>2</sup>C is a two-wire, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the Motherboard converts data and control signals from the PC-104 bus to I<sup>2</sup>C. The data is then fed to the relay board and optional analog input circuitry.

## 12.5.12. POWER UP CIRCUIT


This circuit monitors the +5V power supply during start-up and sets the Analog outputs, External Digital I/O ports, and I<sup>2</sup>C circuitry to specific values until the CPU boots and the instrument software can establish control.

## 12.5.13. POWER SUPPLY/ CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50Hz or 60Hz. Individual units are set up at the factory to accept any combination of these five attributes. As illustrated in Figure 12-22 below, power enters the analyzer through a standard IEC 320 power receptacle located on the rear panel of the instrument. From there it is routed through the ON/OFF switch located in the lower right corner of the front panel.

AC line power is stepped down and converted to DC power by two DC power supplies. One supplies +12 VDC, for various valves and valve options, while a second supply provides +5 VDC and ±15 VDC for logic and analog circuitry as well as the TEC cooler. All AC and DC Voltages are distributed through the relay board.

A 6.75 ampere circuit breaker is built into the ON/OFF switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.



### WARNING

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

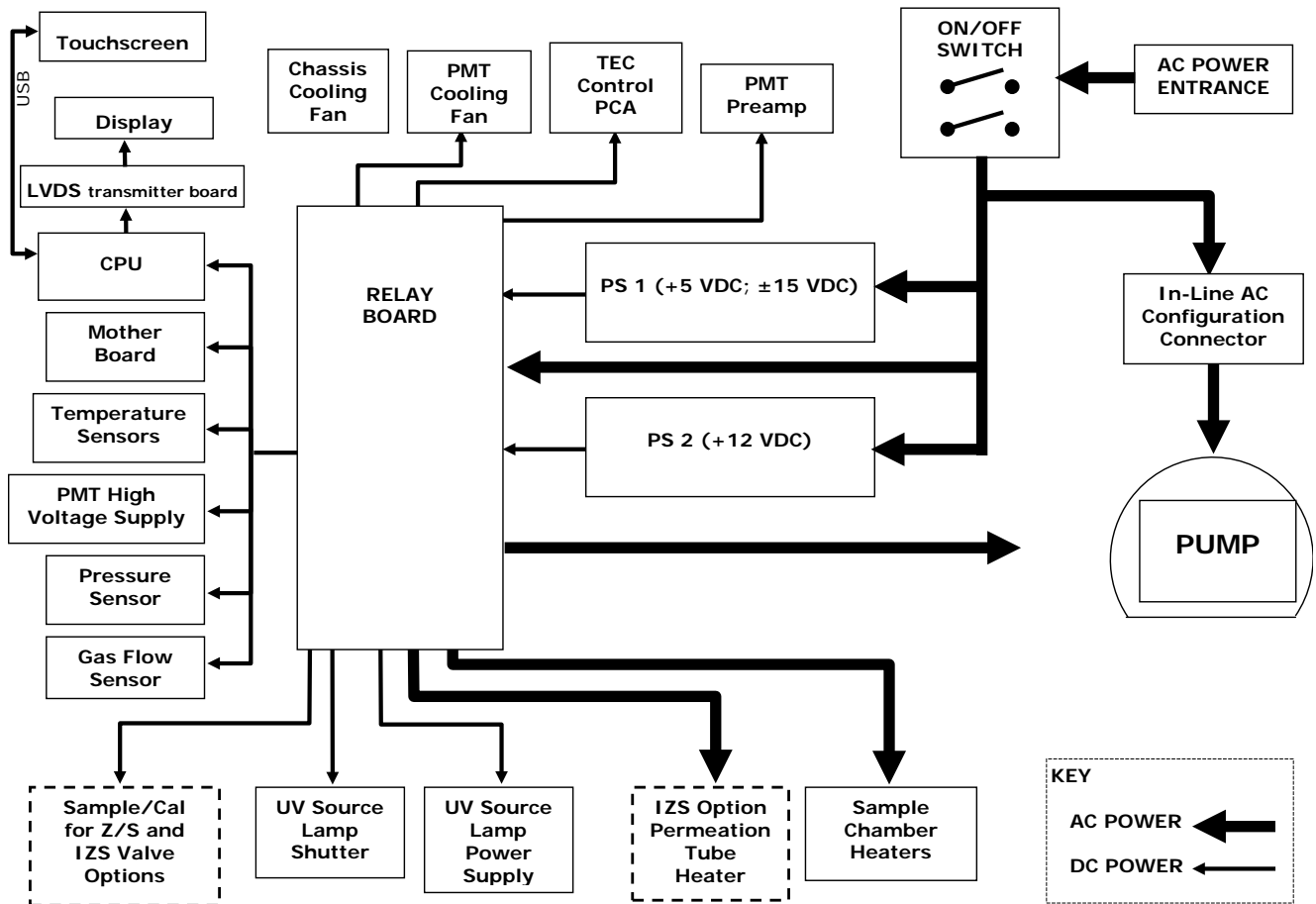


Figure 12-22: Power Distribution Block Diagram



## 12.6. FRONT PANEL/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touch-screen display. The LCD display is controlled directly by the CPU board. The 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.

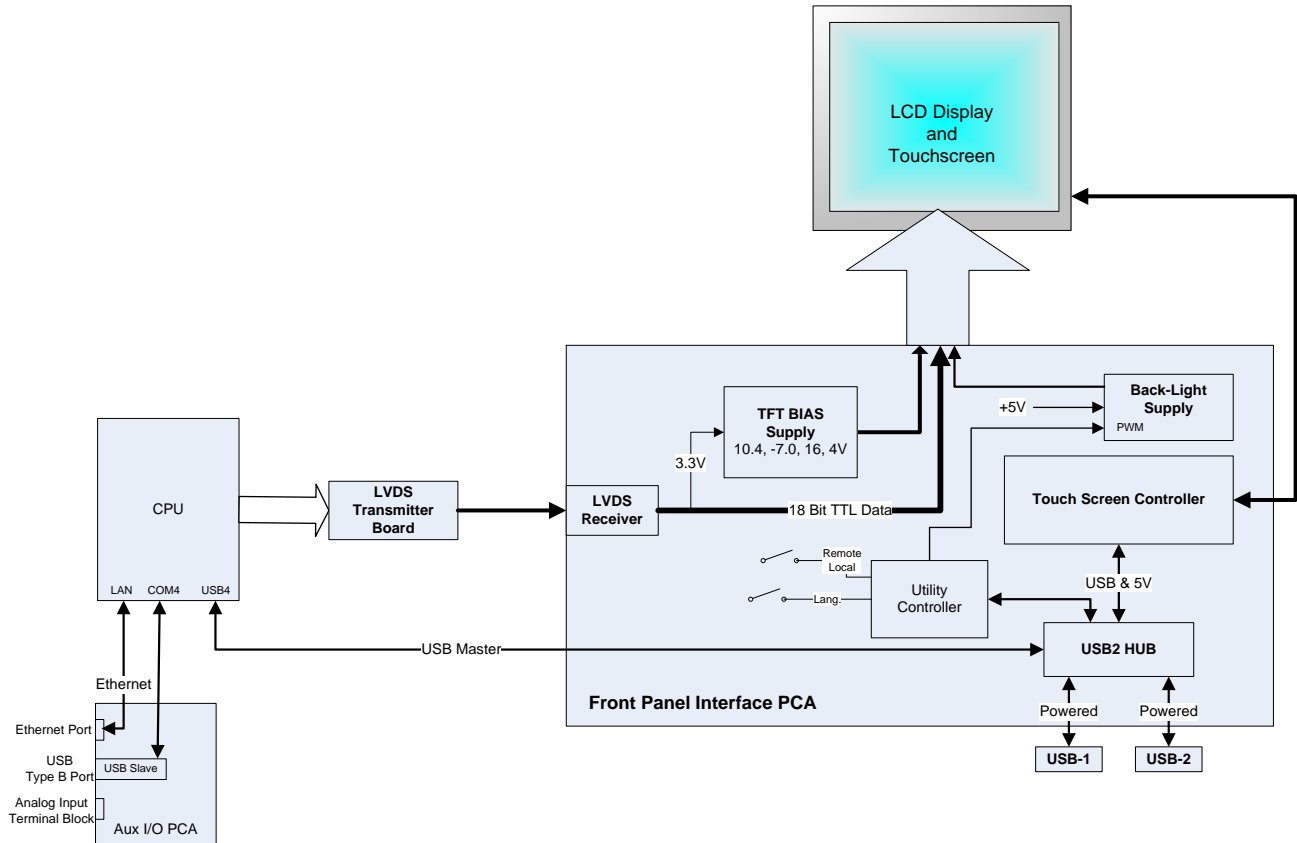


Figure 12-23: Front Panel and Display Interface Block Diagram

### 12.6.1. LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA.

### 12.6.2. 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

## 12.7. SOFTWARE OPERATION

The instrument's core module is a high performance, X86-based microcomputer running Windows CE. Inside Windows CE, special software developed by Teledyne API interprets user commands from the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the gas being sampled.

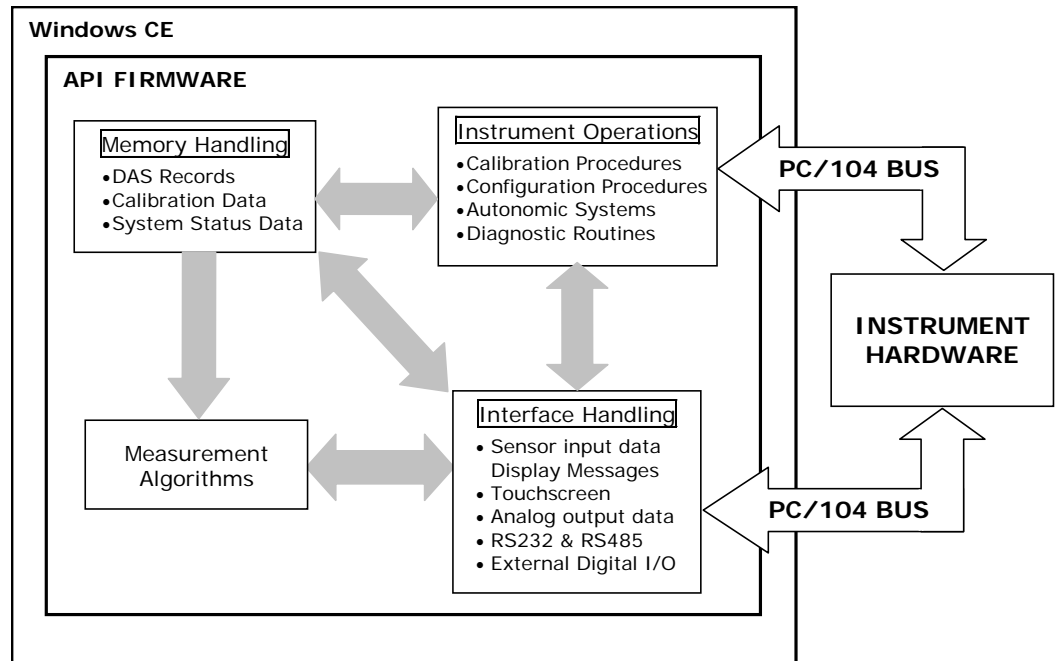


Figure 12-24: Basic Software Operation

### 12.7.1. ADAPTIVE FILTER

The T100 SO<sub>2</sub> analyzer software processes sample gas measurement and reference data through an adaptive filter built into the software. Unlike other analyzers that average the sensor output signal over a fixed time period, the T100 calculates averages over a set number of samples where each sample is 1 second. During operation, the software automatically switches between two filters of different lengths based on the conditions at hand.

During conditions of constant or nearly constant concentration the software computes an average of the last 240 samples or 240 seconds. This provides the calculation portion of the software with smooth, stable readings. If a rapid change in concentration is detected, the adaptive filter switches modes and only averages the last 20 samples or 20 seconds. This allows the analyzer to respond to the rapidly changing concentration more quickly. Once triggered, the short filter remains engaged for a fixed time period to prevent chattering.

Two conditions must be simultaneously met to switch to the short filter. First, the instantaneous concentration must exceed the average in the long filter by a fixed

amount. Second, the instantaneous concentration must exceed the average in the long filter by a portion, or percentage, of the average in the long filter.

If necessary, the filter lengths of these two modes may be changed to any value between 1 and 1000 samples. Long sample lengths provide better signal-to-noise rejection, but poor response times. Conversely, shorter filter lengths result in poor signal-to-noise rejection, but quicker response times.

## 12.7.2. CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in software. During instrument calibration (refer to Section 90) the user enters expected values for zero and span through the front panel touch-screen control buttons and commands the instrument to make readings of sample gases with known concentrations of SO<sub>2</sub>. The readings taken are adjusted, linearized, and compared to the expected values as input. With this information the software computes values for both slope and offset and stores these values in memory for use in calculating the SO<sub>2</sub> concentration of the sample gas.

Instrument slope and offset values recorded during the last calibration can be viewed by pressing the following control buttons sequence:

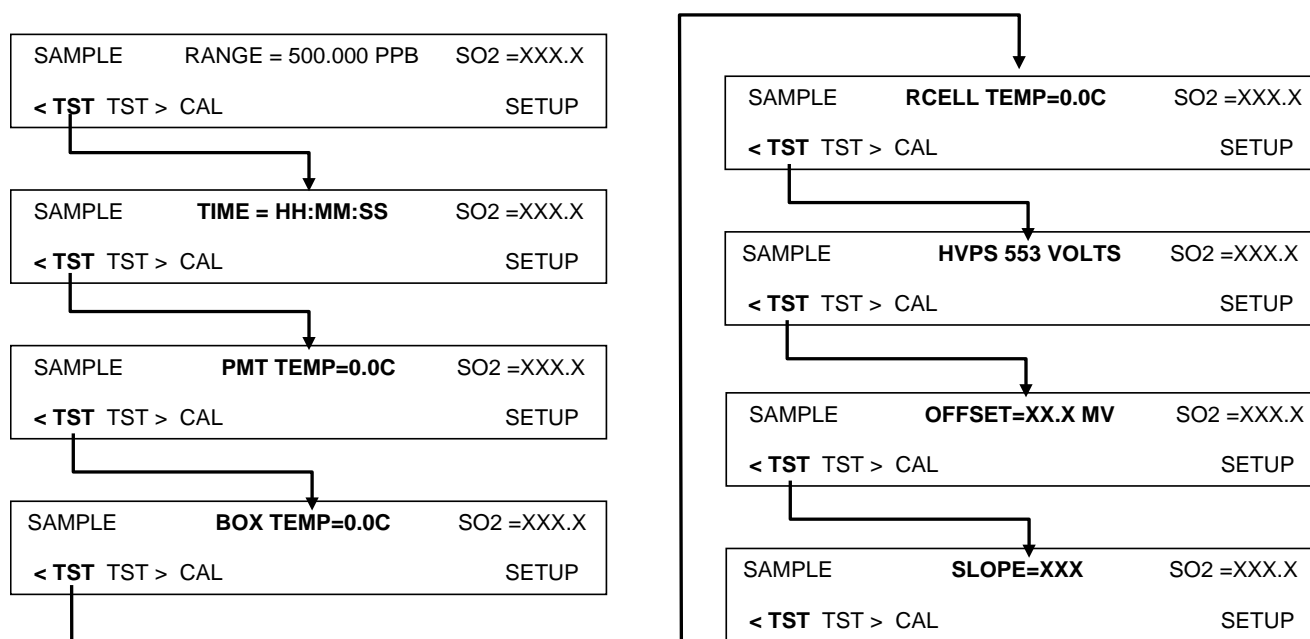


Figure 12-25: Calibration Slope and Offset

## 12.7.3. TEMPERATURE AND PRESSURE COMPENSATION (TPC) FEATURE

As explained in the principles of operation, changes in temperature can significantly affect the amount of fluoresced UV light generated in the instrument's sample chamber. To negate this effect the T100 maintains the sample gas at a stable, raised temperature.

Pressure changes can also have a noticeable, if more subtle, effect on the SO<sub>2</sub> concentration calculation. To account for this, the T100 software includes a feature that allows the instrument to compensate changes in ambient pressure during the SO<sub>2</sub> calculations.

When the TPC feature is enabled, the analyzer's SO<sub>2</sub> concentration is divided by a factor call PRESSCO, which is based on the difference between the ambient pressure of the sample gas normalized to standard atmospheric pressure (Equation 12-6). As ambient pressure increases, the compensated SO<sub>2</sub> concentration is decreased.

$$PRESSCO = \frac{SAMPLE\_PRESSURE (" HG - A) \times SAMP\_PRESS\_SLOPE}{29.92 (" HG - A)}$$

(Equation 12-6)

**SAMPLE-PRESSURE:** The ambient pressure of the sample gas as measured by the instrument's sample pressure sensor in "Hg-A.

**SAMP\_PRESS\_SLOPE:** Sample pressure slope correction factor.

The SETUP>VARS menu enables/disables the TPC feature (see Section 5.8, Table 5-2).

#### 12.7.4. INTERNAL DATA ACQUISITION SYSTEM (DAS)

The DAS is designed to implement predictive diagnostics that store trending data for users to anticipate when an instrument will require service. Large amounts of data can be stored in non-volatile memory and retrieved in plain text format for further processing with common data analysis programs. The DAS has a consistent user interface in all Teledyne API instruments. New data parameters and triggering events can be added to the instrument as needed.

Depending on the sampling frequency and the number of data parameters the DAS can store several months of data, which are retained even when the instrument is powered off or a new firmware is installed. The DAS permits users to access the data through the instrument's front panel or the remote interface. The latter can automatically download stored data for further processing. For information on using the DAS, refer to Section 7.

# GLOSSARY

Note: Some terms in this glossary may not occur elsewhere in this manual.

Term	Description/Definition
10Base-T	an Ethernet standard that uses twisted ("T") pairs of copper wires to transmit at 10 megabits per second (Mbps)
100Base-T	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	<i>Assembly</i>
CAS	<i>Code-Activated Switch</i>
CD	<i>Corona Discharge</i> , a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	<i>Converter Efficiency</i> , the percentage of light energy that is actually converted into electricity
CEM	<i>Continuous Emission Monitoring</i>
Chemical formulas that may be included in this document:	
CO <sub>2</sub>	carbon dioxide
C <sub>3</sub> H <sub>8</sub>	propane
CH <sub>4</sub>	methane
H <sub>2</sub> O	water vapor
HC	general abbreviation for hydrocarbon
HNO <sub>3</sub>	nitric acid
H <sub>2</sub> S	hydrogen sulfide
NO	nitric oxide
NO <sub>2</sub>	nitrogen dioxide
NO <sub>x</sub>	nitrogen oxides, here defined as the sum of NO and NO <sub>2</sub>
NO <sub>y</sub>	nitrogen oxides, often called odd nitrogen: the sum of NO <sub>x</sub> plus other compounds such as HNO <sub>3</sub> (definitions vary widely and may include nitrate (NO <sub>3</sub> ), PAN, N <sub>2</sub> O and other compounds as well)
NH <sub>3</sub>	ammonia
O <sub>2</sub>	molecular oxygen
O <sub>3</sub>	ozone
SO <sub>2</sub>	sulfur dioxide
cm <sup>3</sup>	metric abbreviation for <i>cubic centimeter</i> (replaces the obsolete abbreviation "cc")
CPU	<i>Central Processing Unit</i>
DAC	<i>Digital-to-Analog Converter</i>

Term	Description/Definition
DAS	<i>Data Acquisition System</i>
DCE	<i>Data Communication Equipment</i>
DFU	<i>Dry Filter Unit</i>
DHCP	<i>Dynamic Host Configuration Protocol.</i> A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DIAG	<i>Diagnostics</i> , the diagnostic settings of the analyzer.
DOM	<i>Disk On Module</i> , a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
DOS	<i>Disk Operating System</i>
DRAM	<i>Dynamic Random Access Memory</i>
DR-DOS	<i>Digital Research DOS</i>
DTE	<i>Data Terminal Equipment</i>
EEPROM	<i>Electrically Erasable Programmable Read-Only Memory</i> also referred to as a FLASH chip or drive
ESD	<i>Electro-Static Discharge</i>
ETEST	<i>Electrical Test</i>
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	<i>Fluorinated Ethylene Propylene</i> polymer, one of the polymers that Du Pont markets as Teflon <sup>®</sup>
Flash	non-volatile, solid-state memory
FPI	<i>Fabry-Perot Interface</i> : a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	<i>Gas Filter Correlation</i>
I <sup>2</sup> C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	<i>Integrated Circuit</i> , a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	<i>Internet Protocol</i>
IZS	<i>Internal Zero Span</i>

Term	Description/Definition
LAN	<i>Local Area Network</i>
LCD	<i>Liquid Crystal Display</i>
LED	<i>Light Emitting Diode</i>
LPM	<i>Liters Per Minute</i>
MFC	<i>Mass Flow Controller</i>
M/R	<i>Measure/Reference</i>
MOLAR MASS	<p>the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance.</p> <p>EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams.</p> <p>Atomic weights can be found on any Periodic Table of Elements.</p>
NDIR	<i>Non-Dispersive Infrared</i>
NIST-SRM	<i>National Institute of Standards and Technology - Standard Reference Material</i>
PC	<i>Personal Computer</i>
PCA	<i>Printed Circuit Assembly, the PCB with electronic components, ready to use</i>
PC/AT	<i>Personal Computer / Advanced Technology</i>
PCB	<i>Printed Circuit Board, the bare board without electronic component</i>
PFA	<i>Perfluoroalkoxy, an inert polymer; one of the polymers that Du Pont markets as Teflon<sup>®</sup></i>
PLC	<i>Programmable Logic Controller, a device that is used to control instruments based on a logic level signal coming from the analyzer</i>
PLD	<i>Programmable Logic Device</i>
PLL	<i>Phase Lock Loop</i>
PMT	<i>Photo Multiplier Tube, a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal</i>
P/N (or PN)	<i>Part Number</i>
PSD	<i>Prevention of Significant Deterioration</i>
PTFE	<i>Polytetrafluoroethylene, 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<sup>®</sup></i>
PVC	<i>Poly Vinyl Chloride, a polymer used for downstream tubing</i>
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet

Term	Description/Definition
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between the host and the furthest device
SAROAD	<i>Storage and Retrieval of Aerometric Data</i>
SLAMS	<i>State and Local Air Monitoring Network Plan</i>
SLPM	<i>Standard Liters Per Minute</i> of a gas at standard temperature and pressure
STP	<i>Standard Temperature and Pressure</i>
TCP/IP	<i>Transfer Control Protocol / Internet Protocol</i> , the standard communications protocol for Ethernet devices
TEC	<i>Thermal Electric Cooler</i>
TPC	<i>Temperature/Pressure Compensation</i>
USB	<i>Universal Serial Bus</i> : a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARS	<i>Variables</i> , the variable settings of the instrument
V-F	<i>Voltage-to-Frequency</i>
Z/S	<i>Zero / Span</i>



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# APPENDIX A - Version Specific Software Documentation

## Rev 1.0.3 (T-Series)/G6 (E-Series)

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APPENDIX A-1: Software Menu Trees

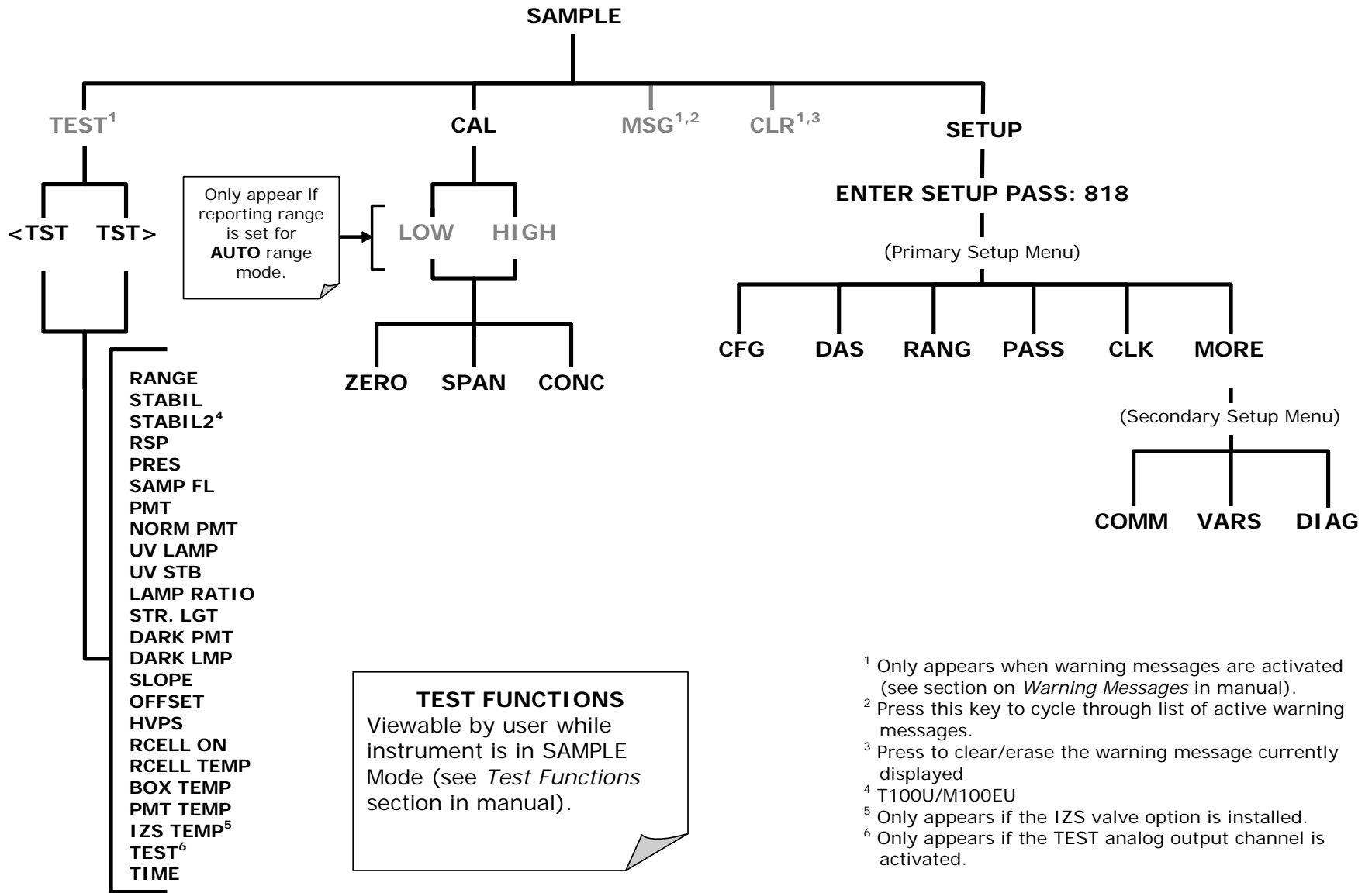
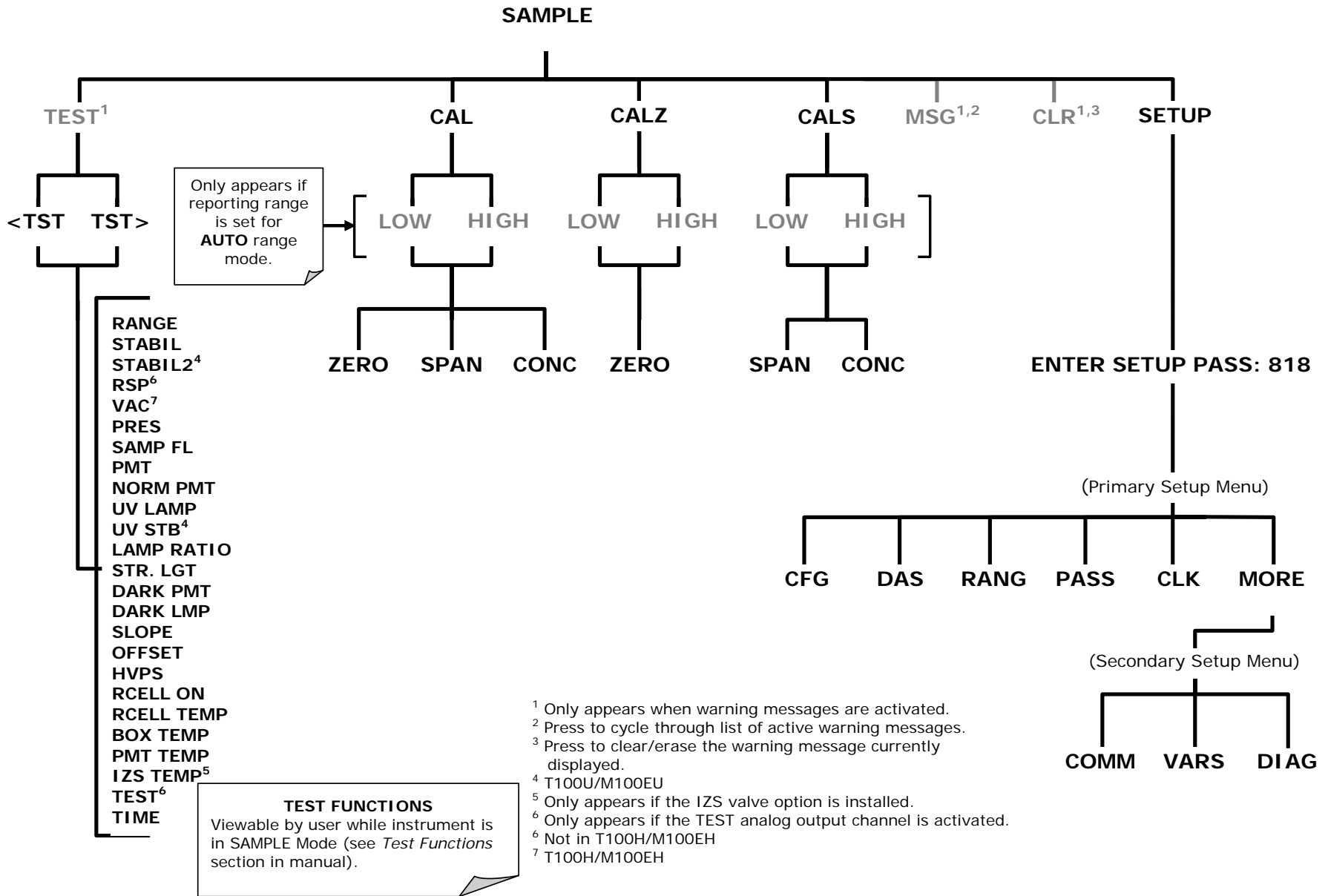


Figure A-1: Basic Sample Display Menu



**Figure A-2: Sample Display Menu - Units with Z/S Valve or IZS Option installed**



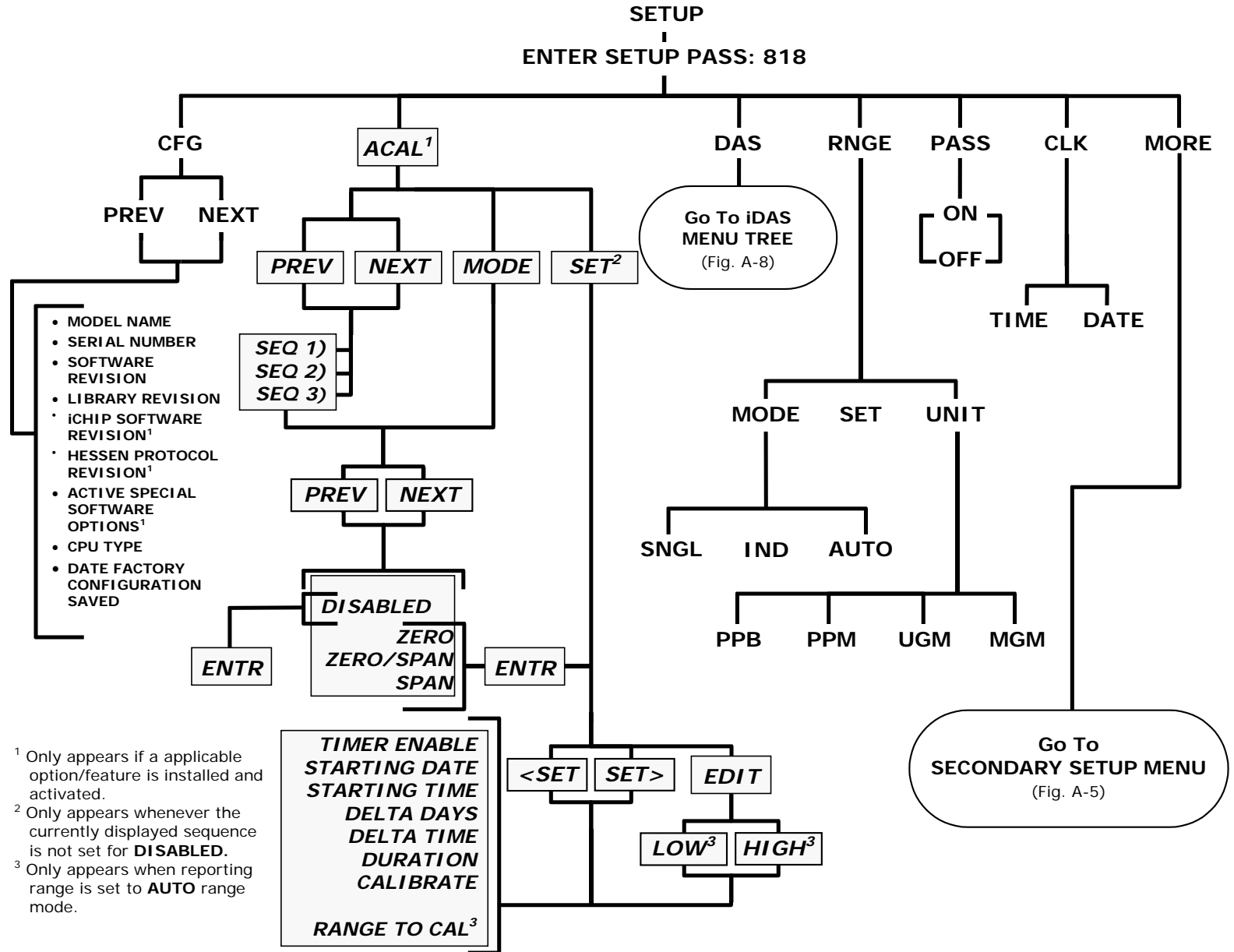


Figure A-3: Primary Setup Menu (Except DAS)

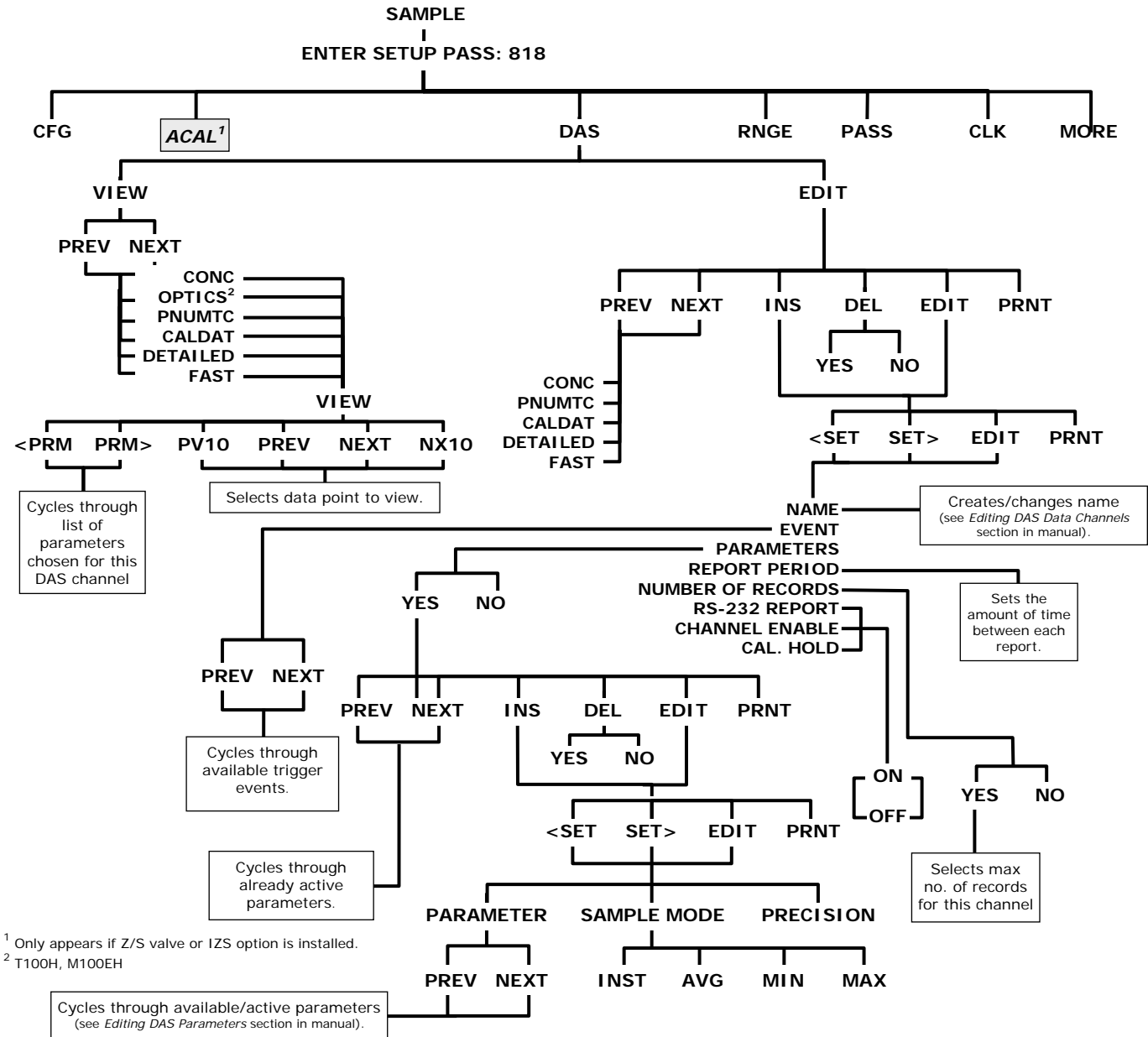


Figure A-4: Primary Setup Menu (DAS)

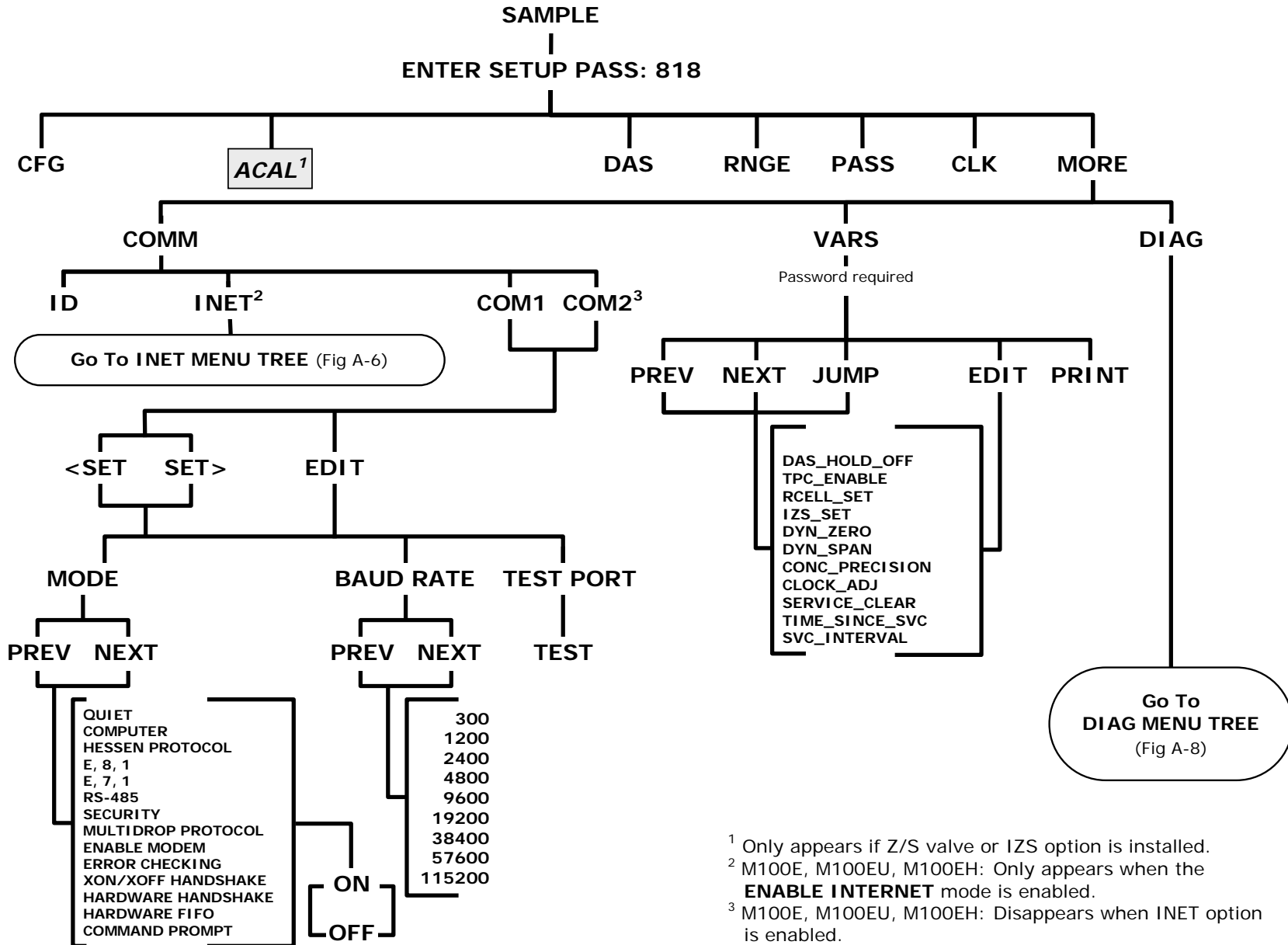
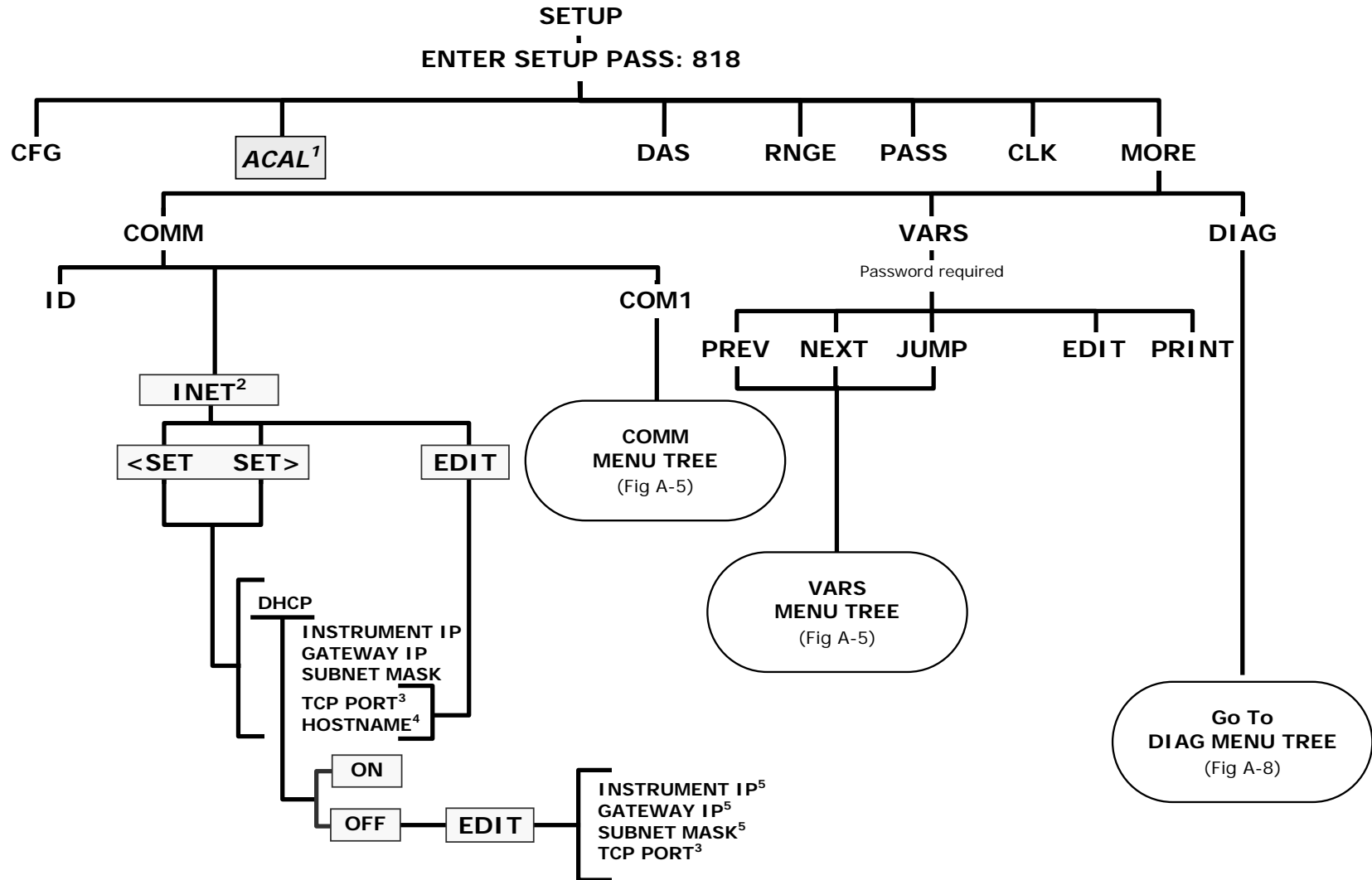


Figure A-5: Secondary Setup Menu (COMM & VARS)



<sup>1</sup> Only appears if a valve option is installed.

<sup>2</sup> M100E, M100EU, M100EH: Only appears when the Ethernet card (option 63) is installed.

<sup>3</sup> M100E, M100EU, M100EH: Although **TCP PORT** is editable regardless of the **DHCP** state, do not change the setting for this property unless instructed to by Teledyne Instruments Customer Service personnel.

<sup>4</sup> **HOST NAME** is only editable when DHCP is **ON**.

<sup>5</sup> **INSTRUMENT IP**, **GATEWAY IP** & **SUBNET MASK** are only editable when DHCP is **OFF**.

**Figure A-6: Secondary Setup, COMM – INET (Ethernet) Menu**

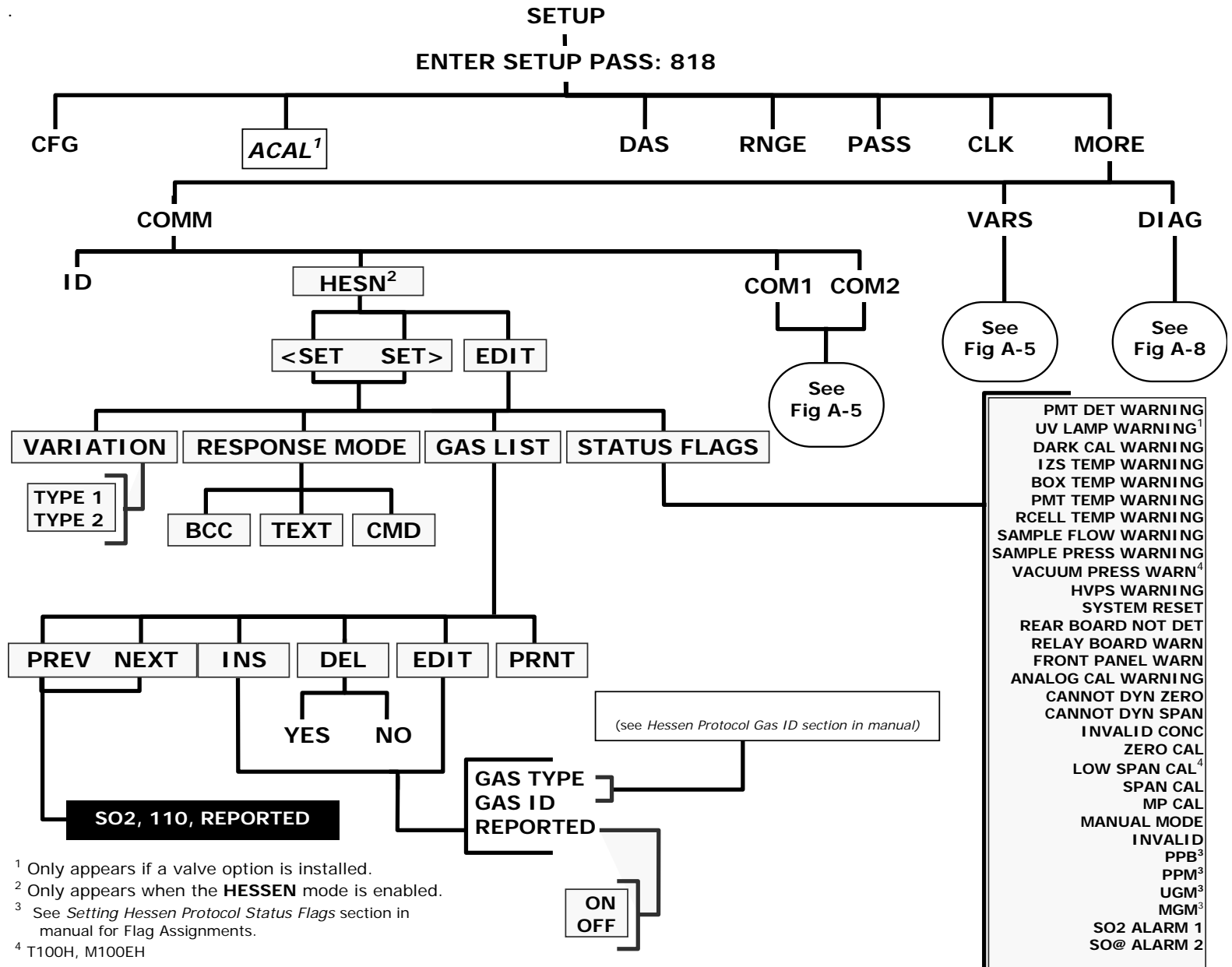


Figure A-7: Secondary Setup Menu - HESSEN Submenu

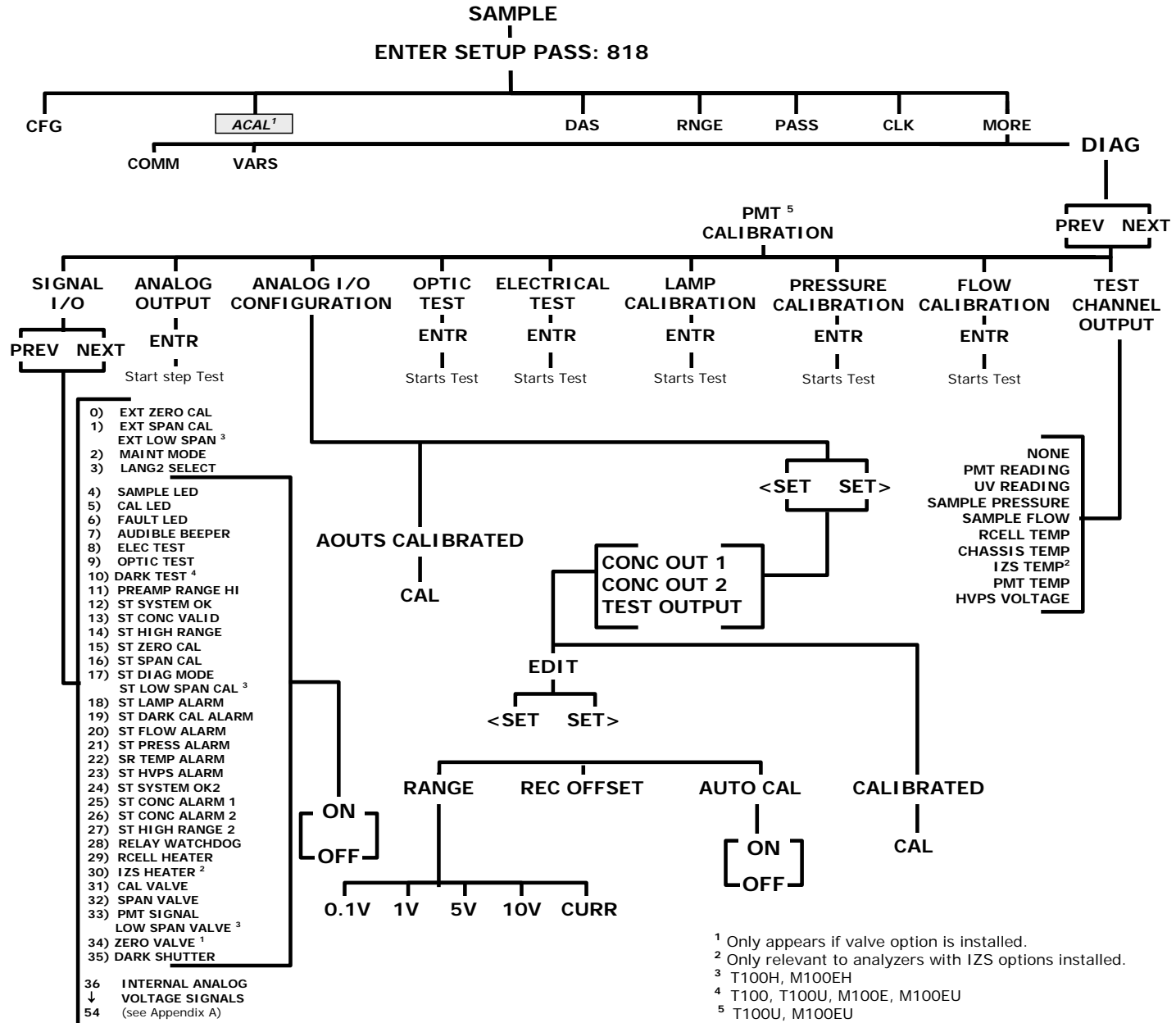


Figure A-8: Secondary Setup Menu (DIAG)

## APPENDIX A-2: Setup Variables For Serial I/O

Table A-1: Setup Variables

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
DAS_HOLD_OFF	Minutes	15	0.5–20	Duration of DAS hold off period.
TPC_ENABLE	—	ON	OFF, ON	ON enables temperature and pressure compensation; OFF disables it.
RCELL_SET	°C	50	30–70	Reaction cell temperature set point and warning limits.
		Warnings: 45–55		
IZS_SET <sup>1</sup>	°C	50	30–70	IZS temperature set point and warning limits.
		Warnings: 45–55		
DYN_ZERO	—	OFF	OFF, ON	ON enables contact closure dynamic zero; OFF disables it.
DYN_SPAN	—	OFF	OFF, ON	ON enables contact closure dynamic span; OFF disables it.
CONC_PRECISION	—	3	AUTO, 0, 1, 2, 3, 4	Number of digits to display to the right of the decimal point for concentrations on the display. Enclose value in double quotes (“”) when setting from the RS-232 interface.
REM_CAL_DURATION <sup>17</sup>	Minutes	20	1–120	Duration of automatic calibration initiated from TAI protocol.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
SERVICE_CLEAR	—	OFF	OFF ON	ON resets the service interval timer.
TIME_SINCE_SVC	Hours	0	0–500000	Time since last service.
SVC_INTERVAL	Hours	0	0–100000	Sets the interval between service reminders.

- <sup>1</sup> T100/M100E.  
<sup>2</sup> M100ES.  
<sup>3</sup> T100H/M100EH.  
<sup>4</sup> Background concentration compensation option (6400E/6400EH).  
<sup>6</sup> Engineering firmware only.  
<sup>7</sup> iChip option.  
<sup>8</sup> Must power-cycle instrument for these options to fully take effect.  
<sup>9</sup> Low span option.  
<sup>10</sup> O<sub>2</sub> option.  
<sup>11</sup> CO<sub>2</sub> option.  
<sup>12</sup> T100U/M100EU.  
<sup>13</sup> Concentration alarm option.  
<sup>17</sup> TAI protocol  
<sup>18</sup> Aging Compensation option.  
<sup>99</sup> Obsolete.

## APPENDIX A-3: Warnings and Test Functions

Table A-2: Warning Messages

NAME	MESSAGE TEXT	DESCRIPTION
<b>Warnings</b>		
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WSO2ALARM1 <sup>7</sup>	SO2 ALARM 1 WARN	SO <sub>2</sub> concentration alarm limit #1 exceeded
WSO2ALARM2 <sup>7</sup>	SO2 ALARM 2 WARN	SO <sub>2</sub> concentration alarm limit #2 exceeded
WO2ALARM1 <sup>10+7</sup>	O2 ALARM 1 WARN	O <sub>2</sub> concentration alarm limit #1 exceeded
WO2ALARM2 <sup>10+7</sup>	O2 ALARM 2 WARN	O <sub>2</sub> concentration alarm limit #2 exceeded
WCO2ALARM1 <sup>11+7</sup>	CO2 ALARM 1 WARN	CO <sub>2</sub> concentration alarm limit #1 exceeded
WCO2ALARM2 <sup>11+7</sup>	CO2 ALARM 2 WARN	CO <sub>2</sub> concentration alarm limit #2 exceeded
WPMT	PMT DET WARNING	PMT detector outside of warning limits.
WUVLAMP	UV LAMP WARNING	UV lamp reading outside of warning limits.
WSAMPFLOW	SAMPLE FLOW WARN	Sample flow outside of warning limits.
WSAMPPRESS	SAMPLE PRESS WARN	Sample pressure outside of warning limits
WVACPRESS <sup>5</sup>	VACUUM PRESS WARN	Vacuum pressure outside of warning.
WBOXTEMP	BOX TEMP WARNING	Chassis temperature outside of warning limits
WRCELLTEMP	RCELL TEMP WARNING	Reaction cell temperature outside of warning.
WO2CELLTEMP <sup>10</sup>	O2 CELL TEMP WARN	O <sub>2</sub> sensor cell temperature outside of warning limits.
WIZSTEMP	IZS TEMP WARNING	IZS temperature outside of warning limits.
WPMTTEMP	PMT TEMP WARNING	PMT temperature outside of warning.
WDARKCAL	DARK CAL WARNING	Dark offset above limit.
WHVPS	HVPS WARNING	High voltage power supply output outside of warning limits.
WDYNZERO	CANNOT DYN ZERO	Contact closure zero calibration failed while <i>DYN_ZERO</i> was set to <i>ON</i> .
WDYNSPAN	CANNOT DYN SPAN	Contact closure span calibration failed while <i>DYN_SPAN</i> was set to <i>ON</i> .
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.
WFRONTPANEL	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.

<sup>1</sup> The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".

<sup>2</sup> Engineering software.

<sup>3</sup> Current instrument units.

<sup>4</sup> T100/M100E.

<sup>5</sup> T100H/M100EH.

<sup>6</sup> T100U/M100EU.

<sup>7</sup> Concentration alarm option.

<sup>10</sup> O<sub>2</sub> option.

<sup>11</sup> CO<sub>2</sub> option.



**Table A-3: Test Functions**

TEST FUNCTION	MESSAGE TEXT	DESCRIPTION
<b>Test Measurements</b>		
RANGE	RANGE=500.0 PPB <sup>3</sup> SO2 RNG=500.0 PPB <sup>3, 10, 11</sup>	D/A range in single or auto-range modes.
RANGE1	RANGE1=500.0 PPB <sup>3</sup> SO2 RN1=500.0 PPB <sup>3, 10, 11</sup>	D/A #1 range in independent range mode.
RANGE2	RANGE2=500.0 PPB <sup>3</sup> SO2 RN2=500.0 PPB <sup>3, 10, 11</sup>	D/A #2 range in independent range mode.
CO2RANGE	CO2 RNG=100 PCT <sup>11</sup>	D/A range for CO <sub>2</sub> concentration.
O2RANGE	O2 RNG=100 PCT <sup>10</sup>	D/A range for O <sub>2</sub> concentration
STABILITY	STABIL=0.0 PPB <sup>3</sup> SO2 STB=0.0 PPB <sup>3, 10</sup> O2 STB=0.0 PCT <sup>10</sup> CO2 STB=0.0 PCT <sup>11</sup>	Concentration stability #1.
STABILITY2 <sup>6</sup>	STABIL2=0.0 PPB <sup>3</sup> SO2 STB2=0.0 PPB <sup>3, 10</sup> O2 STB2=0.0 PCT <sup>10</sup> CO2 STB2=0.0 PCT <sup>11</sup>	Concentration stability #2.
RESPONSE <sup>2</sup>	RSP=1.11(0.00) SEC	Instrument response. Length of each signal processing loop. Time in parenthesis is standard deviation.
VACUUM <sup>5</sup>	VAC=9.1 IN-HG-A	Vacuum pressure.
SAMPPRESS	PRES=29.9 IN-HG-A	Sample pressure.
SAMPFLOW	SAMP FL=700 CC/M	Sample flow rate.
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 <sup>6</sup>	UV STB=5.607 MV	UV lamp stability reading.
LAMP RATIO	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.
SLOPE	SLOPE=1.061	Slope for current range, computed during zero/span calibration.
OFFSET	OFFSET=250.0 MV	Offset for current range, computed during zero/span calibration.
CO2SLOPE <sup>11</sup>	CO2 SLOPE=1.0000	CO <sub>2</sub> slope, computed during zero/span calibration.
CO2OFFSET <sup>11</sup>	CO2 OFFSET=0.00 %	CO <sub>2</sub> offset, computed during zero/span calibration.
O2SLOPE <sup>10</sup>	O2 SLOPE=0.980	O <sub>2</sub> slope, computed during zero/span calibration.
O2OFFSET <sup>10</sup>	O2 OFFSET=1.79 %	O <sub>2</sub> offset, computed during zero/span calibration.
HVPS	HVPS=650 VOLTS	High voltage power supply output.
RCELLDUTY	RCELL ON=0.00 SEC	Reaction cell temperature control duty cycle.
RCELLTEMP	RCELL TEMP=52.1 C	Reaction cell temperature.
O2CELLTEMP <sup>10</sup>	O2 CELL TEMP=50.2 C	O <sub>2</sub> sensor cell temperature.
BOXTEMP	BOX TEMP=35.5 C	Internal chassis temperature.

TEST FUNCTION	MESSAGE TEXT	DESCRIPTION
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
IZSDUTY	IZS ON=0.00 SEC	IZS temperature control duty cycle.
IZSTEMP	IZS TEMP=52.2 C	IZS temperature.
SO2	SO2=261.4 PPB	SO <sub>2</sub> concentration for current range.
CO2 <sup>11</sup>	CO2=0.00 PCT	CO <sub>2</sub> concentration.
O2 <sup>10</sup>	O2=0.00 PCT	O <sub>2</sub> concentration.
TESTCHAN	TEST=3721.1 MV	Value output to <i>TEST_OUTPUT</i> analog output.
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.
XIN1 <sup>12</sup>	AIN1=37.15 EU	External analog input 1 value in engineering units.
XIN2 <sup>12</sup>	AIN2=37.15 EU	External analog input 2 value in engineering units.
XIN3 <sup>12</sup>	AIN3=37.15 EU	External analog input 3 value in engineering units.
XIN4 <sup>12</sup>	AIN4=37.15 EU	External analog input 4 value in engineering units.
XIN5 <sup>12</sup>	AIN5=37.15 EU	External analog input 5 value in engineering units.
XIN6 <sup>12</sup>	AIN6=37.15 EU	External analog input 6 value in engineering units.
XIN7 <sup>12</sup>	AIN7=37.15 EU	External analog input 7 value in engineering units.
XIN8 <sup>12</sup>	AIN8=37.15 EU	External analog input 8 value in engineering units.

<sup>1</sup> The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".

<sup>2</sup> Engineering software.

<sup>3</sup> Current instrument units.

<sup>4</sup> T100/M100E.

<sup>5</sup> T100H/M100EH.

<sup>6</sup> T100U/M100EU.

<sup>7</sup> Concentration alarm option.

<sup>10</sup> O<sub>2</sub> option.

<sup>11</sup> CO<sub>2</sub> option.

<sup>12</sup> External analog input option T-Series only.

**APPENDIX A-4: Signal I/O Definitions**

**Table A-4: T100/M100E Signal I/O Definitions**

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>Internal inputs, U7, J108, pins 9–16 = bits 0–7, default I/O address 322 hex</b>		
	0–7	Spare
<b>AUX board digital outputs, default I<sup>2</sup>C address 30 hex</b>		
ELEC_TEST <sup>3</sup>	0	1 = electrical test on 0 = off
OPTIC_TEST <sup>3</sup>	1	1 = optic test on 0 = off
DARK_TEST <sup>3</sup>	2	1 = dark test on 0 = off
PREAMP_RANGE_HI <sup>3</sup>	3	1 = select high preamp range 0 = select low range
<b>Internal outputs, U8, J108, pins 1–8 = bits 0–7, default I/O address 322 hex</b>		
ELEC_TEST	0	1 = electrical test on 0 = off
OPTIC_TEST	1	1 = optic test on 0 = off
PREAMP_RANGE_HI	2	1 = select high preamp range 0 = select low range
	3–5	Spare
I2C_RESET	6	1 = reset I <sup>2</sup> C peripherals 0 = normal
I2C_DRV_RST	7	0 = hardware reset 8584 chip 1 = normal
<b>Control inputs, U11, J1004, pins 1–6 = bits 0–5, default I/O address 321 hex</b>		
EXT_ZERO_CAL	0	0 = go into zero calibration 1 = exit zero calibration
EXT_SPAN_CAL	1	0 = go into span calibration 1 = exit span calibration
EXT_LOW_SPAN <sup>2,6</sup>	2	0 = go into low span calibration 1 = exit low span calibration
EXT_BKGND_CAL <sup>4</sup>	3	0 = go into background calibration 1 = exit background calibration
	4–5	Spare
	6–7	Always 1
<b>Control inputs, U14, J1006, pins 1–6 = bits 0–5, default I/O address 325 hex</b>		
	0–5	Spare
	6–7	Always 1

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>Control outputs, U17, J1008, pins 1–8 = bits 0–7, default I/O address 321 hex</b>		
	0–7	Spare
<b>Control outputs, U21, J1008, pins 9–12 = bits 0–3, default I/O address 325 hex</b>		
	0–3	Spare
<b>Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex</b>		
ST_SYSTEM_OK2, MB_RELAY_36 <sup>9</sup>	4	1 = system OK 0 = any alarm condition or in diagnostics mode Controlled by MODBUS coil register
ST_CONC_ALARM_1 <sup>12</sup> , MB_RELAY_37 <sup>9</sup>	5	1 = conc. limit 1 exceeded 0 = conc. OK Controlled by MODBUS coil register
ST_CONC_ALARM_2 <sup>12</sup> , MB_RELAY_38 <sup>9</sup>	6	1 = conc. limit 2 exceeded 0 = conc. OK Controlled by MODBUS coil register
ST_HIGH_RANGE2 <sup>13</sup> , MB_RELAY_39 <sup>9</sup>	7	1 = high auto-range in use (mirrors <i>ST_HIGH_RANGE</i> status output) 0 = low auto-range Controlled by MODBUS coil register
<b>A status outputs, U24, J1017, pins 1–8 = bits 0–7, default I/O address 323 hex</b>		
ST_SYSTEM_OK	0	0 = system OK 1 = any alarm condition
ST_CONC_VALID	1	0 = conc. valid 1 = warnings or other conditions that affect validity of concentration
ST_HIGH_RANGE	2	0 = high auto-range in use 1 = low auto-range
ST_ZERO_CAL	3	0 = in zero calibration 1 = not in zero
ST_SPAN_CAL	4	0 = in span calibration 1 = not in span
ST_DIAG_MODE	5	0 = in diagnostic mode 1 = not in diagnostic mode
ST_LOW_SPAN_CAL <sup>2,6</sup>	6	0 = in low span calibration 1 = not in low span
ST_BKGND_CAL <sup>4</sup>	7	0 = in background calibration 1 = not in background calibration

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>B status outputs, U27, J1018, pins 1–8 = bits 0–7, default I/O address 324 hex</b>		
ST_LAMP_ALARM	0	0 = lamp intensity low 1 = lamp intensity OK
ST_DARK_CAL_ALARM	1	0 = dark cal. warning 1 = dark cal. OK
ST_FLOW_ALARM	2	0 = any flow alarm 1 = all flows OK
ST_PRESS_ALARM	3	0 = any pressure alarm 1 = all pressures OK
ST_TEMP_ALARM	4	0 = any temperature alarm 1 = all temperatures OK
ST_HVPS_ALARM	5	0 = HVPS alarm 1 = HVPS OK
ST_CO2_CAL <sup>11</sup>	6	0 = in CO <sub>2</sub> calibration 1 = not in CO <sub>2</sub> calibration
ST_O2_CAL <sup>10</sup>	7	0 = in O <sub>2</sub> calibration 1 = not in O <sub>2</sub> calibration
<b>Front panel I<sup>2</sup>C keyboard, default I<sup>2</sup>C address 4E hex</b>		
MAINT_MODE	5 (input)	0 = maintenance mode 1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language 1 = select first language (English)
SAMPLE_LED	8 (output)	0 = sample LED on 1 = off
CAL_LED	9 (output)	0 = cal. LED on 1 = off
FAULT_LED	10 (output)	0 = fault LED on 1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only) 1 = off

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>Relay board digital output (PCF8575), default I<sup>2</sup>C address 44 hex</b>		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
RCELL_HEATER	1	0 = reaction cell heater on 1 = off
	2–3	Spare
IZS_HEATER	4	0 = IZS heater on 1 = off
O2_CELL_HEATER <sup>10</sup>	5	0 = O <sub>2</sub> sensor cell heater on 1 = off
CAL_VALVE	6	0 = let cal. gas in 1 = let sample gas in
SPAN_VALVE	7	0 = let span gas in 1 = let zero gas in
LOW_SPAN_VALVE <sup>2,6</sup>	8	0 = let low span gas in 1 = let sample gas in
CYLINDER_VALVE <sup>7</sup>	8	0 = open pressurized inlet valve 1 = close valve
ZERO_VALVE <sup>2</sup>	9	0 = let zero gas in 1 = let sample gas in
DARK_SHUTTER	10	0 = close dark shutter 1 = open
	11–15	Spare
<b>AUX board analog inputs, default I<sup>2</sup>C address 30 hex</b>		
PMT_SIGNAL <sup>3</sup>	0 (register number)	PMT detector
UVLAMP_SIGNAL <sup>3</sup>	1	UV lamp intensity
NORM_PMT_SIGNAL <sup>3</sup>	2	Normalized PMT detector
PMT_TEMP <sup>3</sup>	3	PMT temperature
HVPS_VOLTAGE <sup>3</sup>	4	HV power supply output
PMT_DARK <sup>3</sup>	5	PMT reading during dark cycles
LAMP_DARK <sup>3</sup>	6	Lamp reading during dark cycles
AGND_DARK <sup>3</sup>	7	AGND reading during dark cycles
AGND_LIGHT <sup>3</sup>	8	AGND reading during light cycles
VREF_DARK <sup>3</sup>	9	VREF4096 reading during dark cycles
VREF_LIGHT <sup>3</sup>	10	VREF4096 reading during light cycles

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>Rear board primary MUX analog inputs</b>		
PMT_SIGNAL	0	PMT detector
HVPS_VOLTAGE	1	HV power supply output
PMT_TEMP	2	PMT temperature
UVLAMP_SIGNAL	3	UV lamp intensity
	4	Temperature MUX
PHOTO_ABS <sup>8</sup>	5	Pre-amplified UV lamp intensity
O2_SENSOR <sup>10</sup>	6	O <sub>2</sub> concentration sensor
SAMPLE_PRESSURE	7	Sample pressure
TEST_INPUT_8	8	Diagnostic test input
REF_4096_MV	9	4.096V reference from MAX6241
SAMPLE_FLOW	10	Sample flow rate
VACUUM_PRESSURE <sup>2</sup>	10	Vacuum pressure
CO2_SENSOR <sup>11</sup>	11	CO <sub>2</sub> concentration sensor
	12–13	Spare (thermocouple input?)
	14	DAC MUX
REF_GND	15	Ground reference
<b>Rear board temperature MUX analog inputs</b>		
BOX_TEMP	0	Internal box temperature
RCELL_TEMP	1	Reaction cell temperature
IZS_TEMP	2	IZS temperature
	3	Spare
O2_CELL_TEMP <sup>10</sup>	4	O <sub>2</sub> sensor cell temperature
TEMP_INPUT_5	5	Diagnostic temperature input
TEMP_INPUT_6	6	Diagnostic temperature input
	7	Spare
<b>Rear board DAC MUX analog inputs</b>		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback
<b>Rear board analog outputs</b>		
CONC_OUT_1, DATA_OUT_1	0	Concentration output #1 (SO <sub>2</sub> , range #1), Data output #1
CONC_OUT_2, DATA_OUT_2	1	Concentration output #2 (SO <sub>2</sub> , range #2), Data output #2
CONC_OUT_3 <sup>10</sup> , DATA_OUT_3	2	Concentration output #3 (CO <sub>2</sub> or O <sub>2</sub> ), Data output #3
TEST_OUTPUT, DATA_OUT_4	3	Test measurement output, Data output #4

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
<b>I<sup>2</sup>C analog output (AD5321), default I<sup>2</sup>C address 18 hex</b>		
LAMP_POWER <sup>5</sup>	0	Lamp power (0–5V)
<sup>1</sup> Optional. <sup>2</sup> T100H/M100EH. <sup>3</sup> T100U/M100EU. <sup>4</sup> Background concentration compensation option (6400E/6400EH). <sup>5</sup> Engineering firmware only. <sup>6</sup> Low span option. <sup>7</sup> Pressurized IZS option. <sup>8</sup> T100/M100E. <sup>9</sup> MODBUS option. <sup>10</sup> O <sub>2</sub> option. <sup>11</sup> CO <sub>2</sub> option. <sup>12</sup> Concentration alarm option. <sup>13</sup> High auto range relay option		



**APPENDIX A-5: DAS Functions**

**Table A-5: DAS Trigger Events, Software Version G.4**

NAME	DESCRIPTION
ATIMER	Automatic timer expired
EXITZR	Exit zero calibration mode
EXITLS <sup>2,3</sup>	Exit low span calibration mode
EXITHS	Exit high span calibration mode
EXITMP	Exit multi-point calibration mode
EXITBK <sup>5</sup>	Exit background calibration mode
EXITO2 <sup>10</sup>	Exit O <sub>2</sub> calibration mode
SLPCHG	Slope and offset recalculated
CO2SLC <sup>11</sup>	CO <sub>2</sub> slope and offset recalculated
O2SLPC <sup>10</sup>	O <sub>2</sub> slope and offset recalculated
EXITDG	Exit diagnostic mode
PMTDTW	PMT detector warning
UVLMPW	UV lamp warning
DRKCLW	Dark calibration warning
CONCW1 <sup>4</sup>	Concentration limit 1 exceeded
CONCW2 <sup>4</sup>	Concentration limit 2 exceeded
RCTMPW	Reaction cell temperature warning
O2TMPW <sup>10</sup>	O <sub>2</sub> sensor cell temperature warning
IZTMPW <sup>1</sup>	IZS temperature warning
PTEMPW	PMT temperature warning
SFLOWW	Sample flow warning
SPRESW	Sample pressure warning
VPRESW <sup>2</sup>	Vacuum pressure warning
BTEMPW	Box temperature warning
HVPSW	High voltage power supply warning
<sup>1</sup> T100/M100E. <sup>2</sup> T100H/M100EH. <sup>3</sup> Low span option. <sup>4</sup> Concentration alarm option. <sup>5</sup> Background concentration compensation option (6400E/6400EH). <sup>10</sup> O <sub>2</sub> option. <sup>11</sup> CO <sub>2</sub> option.	

**Table A-6: DAS Parameters**

NAME	DESCRIPTION	UNITS
PMTDET	PMT detector reading	mV
PHABS <sup>1</sup>	Pre-amplified UV lamp intensity reading	mV
UVDET	UV lamp intensity reading	mV
LAMPR	UV lamp ratio of calibrated intensity	%
DRKPMT	PMT electrical offset	mV
DARKUV	UV lamp electrical offset	mV
SLOPE1	SO <sub>2</sub> slope for range #1	—
SLOPE2	SO <sub>2</sub> slope for range #2	—
OFSET1	SO <sub>2</sub> offset for range #1	mV
OFSET2	SO <sub>2</sub> offset for range #2	mV
CO2SLP <sup>11</sup>	CO <sub>2</sub> slope	—
CO2OFS <sup>11</sup>	CO <sub>2</sub> offset	%
O2SLPE <sup>10</sup>	O <sub>2</sub> slope	—
O2OFST <sup>10</sup>	O <sub>2</sub> offset	%
ZSCNC1	SO <sub>2</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB, PPM <sup>2</sup>
ZSCNC2	SO <sub>2</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
CO2ZSC <sup>11</sup>	CO <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
O2ZSCN <sup>10</sup>	O <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
CONC1	SO <sub>2</sub> concentration for range #1	PPB
CONC2	SO <sub>2</sub> concentration for range #2	PPB
CNCBK1 <sup>4</sup>	SO <sub>2</sub> concentration plus background concentration for range #1	PPB
CNCBK2 <sup>4</sup>	SO <sub>2</sub> concentration plus background concentration for range #2	PPB
BKGND1 <sup>4</sup>	Background concentration for range #1	PPB
BKGND2 <sup>4</sup>	Background concentration for range #2	PPB
SO2CR1 <sup>12</sup>	SO <sub>2</sub> concentration for range #1, with O <sub>2</sub> correction	PPB
SO2CR2 <sup>12</sup>	SO <sub>2</sub> concentration for range #2, with O <sub>2</sub> correction	PPB
CO2CNC <sup>11</sup>	CO <sub>2</sub> concentration	%
O2CONC <sup>10</sup>	O <sub>2</sub> concentration	%
STABIL	Concentration stability #1	PPB
STABL2 <sup>3</sup>	Concentration stability #2	PPB
STABUV <sup>3</sup>	UV lamp stability	mV
STRLGT	Stray light reading	PPB
RCTEMP	Reaction cell temperature	°C
O2TEMP <sup>10</sup>	O <sub>2</sub> sensor cell temperature	°C
IZSTMP <sup>1</sup>	IZS temperature	°C
PMTTMP	PMT temperature	°C
SMPFLW	Sample flow	cc/m
SMPPRS	Sample pressure	"Hg

NAME	DESCRIPTION	UNITS
VACUUM <sup>2</sup>	Vacuum pressure	"Hg
BOXTMP	Internal box temperature	°C
HVPS	High voltage power supply output	Volts
TEST8	Diagnostic test input (TEST_INPUT_8)	mV
TEMP5	Diagnostic temperature input (TEMP_INPUT_5)	°C
TEMP6	Diagnostic temperature input (TEMP_INPUT_6)	°C
REFGND	Ground reference (REF_GND)	mV
RF4096	4096 mV reference (REF_4096_MV)	mV
XIN1 <sup>13</sup>	Channel 1 Analog In	
XIN1SLPE <sup>13</sup>	Channel 1 Analog In Slope	
XIN1OFST <sup>13</sup>	Channel 1 Analog In Offset	
XIN2 <sup>13</sup>	Channel 2 Analog In	
XIN2SLPE <sup>13</sup>	Channel 2 Analog In Slope	
XIN2OFST <sup>13</sup>	Channel 2 Analog In Offset	
XIN3 <sup>13</sup>	Channel 3 Analog In	
XIN3SLPE <sup>13</sup>	Channel 3 Analog In Slope	
XIN3OFST <sup>13</sup>	Channel 3 Analog In Offset	
XIN4 <sup>13</sup>	Channel 4 Analog In	
XIN4SLPE <sup>13</sup>	Channel 4 Analog In Slope	
XIN4OFST <sup>13</sup>	Channel 4 Analog In Offset	
XIN5 <sup>13</sup>	Channel 5 Analog In	
XIN5SLPE <sup>13</sup>	Channel 5 Analog In Slope	
XIN5OFST <sup>13</sup>	Channel 5 Analog In Offset	
XIN6 <sup>13</sup>	Channel 6 Analog In	
XIN6SLPE <sup>13</sup>	Channel 6 Analog In Slope	
XIN6OFST <sup>13</sup>	Channel 6 Analog In Offset	
XIN7 <sup>13</sup>	Channel 7 Analog In	
XIN7SLPE <sup>13</sup>	Channel 7 Analog In Slope	
XIN7OFST <sup>13</sup>	Channel 7 Analog In Offset	
XIN8 <sup>13</sup>	Channel 8 Analog In	
XIN8SLPE <sup>13</sup>	Channel 8 Analog In Slope	
XIN8OFST <sup>13</sup>	Channel 8 Analog In Offset	
AGNDDK <sup>3</sup>	AGND reading during dark cycles	mV
AGNDLT <sup>3</sup>	AGND reading during light cycles	mV
RF4VDK <sup>3</sup>	VREF4096 reading during dark cycles	mV
RF4VLT <sup>3</sup>	VREF4096 reading during light cycles	mV

NAME	DESCRIPTION	UNITS
1	T100/M100E.	
2	T100H/M100EH.	
3	T100U/M100EU.	
4	Background concentration compensation option (6400E/6400EH).	
10	O <sub>2</sub> option.	
11	CO <sub>2</sub> option.	
12	SO <sub>2</sub> with O <sub>2</sub> correction option.	
13	Analog In option, T-Series only.	

## APPENDIX A-6: Terminal Command Designators

Table A-7: Terminal Command Designators

COMMAND	ADDITIONAL COMMAND SYNTAX	DESCRIPTION
? [ID]		Display help screen and this list of commands
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL name hexmask	Display test(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL name hexmask	Disable test(s)
W [ID]	SET ALL name hexmask	Display warning(s)
	LIST [ALL name hexmask] [NAMES HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL name hexmask	Clear warning(s)
C [ID]	ZERO LOWSPAN SPAN [1 2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
	PRINT ["name"] [SCRIPT]	Print DAS configuration
	RECORDS ["name"]	Print number of DAS records
	REPORT ["name"] [RECORDS=number] [FROM=<start date>][TO=<end date>][VERBOSE COMPACT HEX] (Print DAS records)(date format: MM/DD/YYYY(or YY) [HH:MM:SS])	Print DAS records
CANCEL	Halt printing DAS records	
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode
	DASBEGIN [<data channel definitions>] DASEND	Upload DAS configuration
	CHANNELBEGIN propertylist CHANNELEND	Upload single DAS channel
	CHANNELDELETE ["name"]	Delete DAS channels

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

<b>TERMINAL KEY ASSIGNMENTS</b>	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
<b>COMPUTER MODE KEY ASSIGNMENTS</b>	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

**APPENDIX A-7: MODBUS Register Map**

<b>MODBUS Register Address (dec., 0-based)</b>	<b>Description</b>	<b>Units</b>
<b>MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)</b>		
0	PMT detector reading	mV
2	UV lamp intensity reading	mV
4	UV lamp ratio of calibrated intensity	%
6	PMT electrical offset	mV
8	UV lamp electrical offset	mV
10	SO <sub>2</sub> slope for range #1	—
12	SO <sub>2</sub> slope for range #2	—
14	SO <sub>2</sub> offset for range #1	mV
16	SO <sub>2</sub> offset for range #2	mV
18	SO <sub>2</sub> concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB, PPM <sup>2</sup>
20	SO <sub>2</sub> concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	SO <sub>2</sub> concentration for range #1	PPB
24	SO <sub>2</sub> concentration for range #2	PPB
26	Concentration stability	PPB
28	Stray light reading	PPB
30	Reaction cell temperature	°C
32	PMT temperature	°C
34	Sample pressure	"Hg
36	Internal box temperature	°C
38	High voltage power supply output	Volts
40	Diagnostic test input (TEST_INPUT_8)	mV
42	Diagnostic temperature input (TEMP_INPUT_5)	°C
44	Diagnostic temperature input (TEMP_INPUT_6)	°C
46	Ground reference (REF_GND)	mV
48	4096 mV reference (REF_4096_MV)	mV
50	Sample flow	cc/m
52 <sup>1</sup>	IZS temperature	°C
54 <sup>2</sup>	Vacuum pressure	"Hg
56 <sup>1</sup>	Pre-amplified UV lamp intensity reading	mV
100 <sup>10</sup>	O <sub>2</sub> concentration	%
102 <sup>10</sup>	O <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
104 <sup>10</sup>	O <sub>2</sub> slope	—
106 <sup>10</sup>	O <sub>2</sub> offset	%
108 <sup>10</sup>	O <sub>2</sub> sensor cell temperature	°C

<b>MODBUS Register Address (dec., 0-based)</b>	<b>Description</b>	<b>Units</b>
110 <sup>12</sup>	SO <sub>2</sub> concentration for range #1, with O <sub>2</sub> correction	PPB
112 <sup>12</sup>	SO <sub>2</sub> concentration for range #2, with O <sub>2</sub> correction	PPB
130 <sup>14</sup>	External analog input 1 value	Volts
132 <sup>14</sup>	External analog input 1 slope	eng unit /V
134 <sup>14</sup>	External analog input 1 offset	eng unit
136 <sup>14</sup>	External analog input 2 value	Volts
138 <sup>14</sup>	External analog input 2 slope	eng unit /V
140 <sup>14</sup>	External analog input 2 offset	eng unit
142 <sup>14</sup>	External analog input 3 value	Volts
144 <sup>14</sup>	External analog input 3 slope	eng unit /V
146 <sup>14</sup>	External analog input 3 offset	eng unit
148 <sup>14</sup>	External analog input 4 value	Volts
150 <sup>14</sup>	External analog input 4 slope	eng unit /V
152 <sup>14</sup>	External analog input 4 offset	eng unit
154 <sup>14</sup>	External analog input 5 value	Volts
156 <sup>14</sup>	External analog input 5 slope	eng unit /V
158 <sup>14</sup>	External analog input 5 offset	eng unit
160 <sup>14</sup>	External analog input 6 value	Volts
162 <sup>14</sup>	External analog input 6 slope	eng unit /V
164 <sup>14</sup>	External analog input 6 offset	eng unit
166 <sup>14</sup>	External analog input 7 value	Volts
168 <sup>14</sup>	External analog input 7 slope	eng unit /V
170 <sup>14</sup>	External analog input 7 offset	eng unit
172 <sup>14</sup>	External analog input 8 value	Volts
174 <sup>14</sup>	External analog input 8 slope	eng unit /V
176 <sup>14</sup>	External analog input 8 offset	eng unit
200 <sup>11</sup>	CO <sub>2</sub> concentration	%
202 <sup>11</sup>	CO <sub>2</sub> concentration during zero/span calibration, just before computing new slope and offset	%
204 <sup>11</sup>	CO <sub>2</sub> slope	—
206 <sup>11</sup>	CO <sub>2</sub> offset	%
<b>MODBUS Floating Point Holding Registers (32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)</b>		
0	Maps to <i>SO2_SPAN1</i> variable; target conc. for range #1	Conc. units
2	Maps to <i>SO2_SPAN2</i> variable; target conc. for range #2	Conc. units
100 <sup>10</sup>	Maps to <i>O2_TARG_SPAN_CONC</i> variable	%
200 <sup>11</sup>	Maps to <i>CO2_TARG_SPAN_CONC</i> variable	%



MODBUS Register Address (dec., 0-based)	Description	Units
<b>MODBUS Discrete Input Registers (single-bit; read-only)</b>		
0	PMT detector warning	
1	UV detector warning	
2	Dark calibration warning	
3	Box temperature warning	
4	PMT temperature warning	
5	Reaction cell temperature warning	
6	Sample pressure warning	
7	HVPS warning	
8	System reset warning	
9	Rear board communication warning	
10	Relay board communication warning	
11	Front panel communication warning	
12	Analog calibration warning	
13	Dynamic zero warning	
14	Dynamic span warning	
15	Invalid concentration	
16	In zero calibration mode	
17	In span calibration mode	
18	In multi-point calibration mode	
19	System is OK (same meaning as <i>SYSTEM_OK</i> I/O signal)	
20	Sample flow warning	
21 <sup>1</sup>	IZS temperature warning	
22 <sup>2</sup>	In low span calibration mode	
23 <sup>2</sup>	Vacuum pressure warning	
24 <sup>3</sup>	SO <sub>2</sub> concentration alarm limit #1 exceeded	
25 <sup>3</sup>	SO <sub>2</sub> concentration alarm limit #2 exceeded	
26	In Hessen manual mode	
100 <sup>10</sup>	In O <sub>2</sub> calibration mode	
101 <sup>10</sup>	O <sub>2</sub> cell temperature warning	
102 <sup>10+3</sup>	O <sub>2</sub> concentration alarm limit #1 exceeded	
103 <sup>10+3</sup>	O <sub>2</sub> concentration alarm limit #2 exceeded	
200 <sup>11</sup>	In CO <sub>2</sub> calibration mode	
201 <sup>11+3</sup>	CO <sub>2</sub> concentration alarm limit #1 exceeded	
202 <sup>11+3</sup>	CO <sub>2</sub> concentration alarm limit #2 exceeded	

MODBUS Register Address (dec., 0-based)	Description	Units
<b>MODBUS Coil Registers (single-bit; read/write)</b>		
0	Maps to relay output signal 36 ( <i>MB_RELAY_36</i> in signal I/O list)	
1	Maps to relay output signal 37 ( <i>MB_RELAY_37</i> in signal I/O list)	
2	Maps to relay output signal 38 ( <i>MB_RELAY_38</i> in signal I/O list)	
3	Maps to relay output signal 39 ( <i>MB_RELAY_39</i> in signal I/O list)	
20 <sup>13</sup>	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 <sup>13</sup>	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 <sup>13</sup>	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 <sup>13</sup>	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	
<sup>1</sup> M100E. <sup>2</sup> M100EH. <sup>3</sup> Concentration alarm option. <sup>10</sup> O <sub>2</sub> option. <sup>11</sup> CO <sub>2</sub> option. <sup>12</sup> SO <sub>2</sub> with O <sub>2</sub> correction option. <sup>13</sup> Set <i>DYN_ZERO</i> or <i>DYN_SPAN</i> variables to <i>ON</i> to enable calculating new slope or offset. Otherwise a calibration check is performed. <sup>14</sup> External analog input option.		

## APPENDIX B - Spare Parts

Note

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Use of replacement parts other than those supplied by API may result in non compliance with European standard EN 61010-1.  
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Note

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Due to the dynamic nature of part numbers, please refer to the Website or call Sales for more recent updates to the Spare Parts list.  
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Part Number	Description
000940100	ORIFICE, 3 MIL, IZS
000940400	CD, ORIFICE, .004 BLUE
000940800	ORIFICE, 012 MIL, RXCELL
002690000	LENS, UV
002700000	LENS, PMT
002720000	FILTER, PMT OPTICAL, 330 NM
003290000	ASSY, THERMISTOR
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)
012720100	OPTION, NO <sub>x</sub> OPTICAL FILTER *
013140000	ASSY, COOLER FAN (NOX/SOX)
013210000	ASSY, VACUUM MANIFOLD
013390000	ASSY, KICKER
013400000	CD, PMT, SO <sub>2</sub> , (KB)
013420000	ASSY, ROTARY SOLENOID
013570000	ASSY, THERMISTOR (COOLER)
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, TFE RETAINER, SAMPLE FILTER
040010000	ASSY, FAN REAR PANEL
040030100	PCA, FLOW/PRESSURE
041620100	ASSY, SO <sub>2</sub> SENSOR (KB)
041800400	PCA, PMT PREAMP, VR
041920000	ASSY, THERMISTOR
042410200	ASSY, PUMP, INT, E SERIES
043420000	ASSY, HEATER/THERM, O <sub>2</sub> SEN
043570000	AKIT, EXPENDABLES
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >455
046250000	ASSY, RXCELL HEATER/FUSE
046260000	ASSY, THERMISTOR, RXCELL (KB)
048830000	AKIT, EXP KIT, EXHAUST CLNSR, SILCA GEL
049310100	PCA, TEC CONTROL, E SERIES
050510200	PUMP, INT, 115/240V * (KB)
050610100	CONFIGURATION PLUGS, 115V/60Hz
050610200	CONFIGURATION PLUGS, 115V/50Hz
050610300	CONFIGURATION PLUGS, 220-240V/50Hz
050610400	CONFIGURATION PLUGS, 220-240V/60Hz
050630100	PCA, M100E UV REF DETECTOR
051990000	ASSY, SCRUBBER, INLINE EXHAUST, DISPOS

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Part Number	Description
052660000	ASSY, HEATER/THERMISTOR (IZS)
055100200	ASSY, OPTION, PUMP, 240V *
055560000	ASSY, VALVE, VA59 W/DIODE, 5" LEADS
055560100	ASSY, VALVE, VA59 W/DIODE, 9" LEADS
058021100	PCA,E-SERIES MOTHERBD, GEN 5 ICOP (ACCEPTS ACROSSER OR ICOP CPU)
061930000	PCA, UV LAMP DRIVER, GEN-2 43mA *
062420200	PCA, SER INTRFACE, ICOP CPU, E- (OPTION) (USE WITH ICOP CPU 062870000)
066970000	PCA, INTRF. LCD TOUCH SCRNR, 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
068070000	MANUAL, OPERATORS, T100
068220100	DOM, w/SOFTWARE, T100 *
068810000	PCA, LVDS TRANSMITTER BOARD
069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	CONNECTOR, REAR PANEL, 12 PIN
CN0000520	CONNECTOR, REAR PANEL, 10 PIN
FL0000001	FILTER, FLOW CONTROL
FL0000003	FILTER, DFU (KB)
FM0000004	FLOWMETER (KB)
HW0000005	FOOT, CHASSIS
HW0000020	SPRING, FLOW CONTROL
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
OP0000030	OXYGEN TRANSDUCER, PARAMAGNETIC
OP0000031	WINDOW, QUARTZ, REF DETECTOR
OR0000001	ORING, FLOW CONTROL/IZS
OR0000004	ORING, OPTIC/CELL, CELL/TRAP
OR0000006	ORING, CELL/PMT
OR0000007	ORING, PMT/BARREL/CELL
OR0000015	ORING, PMT FILTER

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Part Number	Description
OR0000016	ORING, UV LENS
OR0000025	ORING, ZERO AIR SCRUBBER
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK
OR0000039	ORING, QUARTZ WINDOW/REF DETECTOR
OR0000046	ORING, PERMEATION OVEN
OR0000083	ORING, PMT SIGNAL & OPTIC LED
OR0000084	ORING, UV FILTER
OR0000094	ORING, SAMPLE FILTER
PU0000022	KIT, PUMP REBUILD
RL0000015	RELAY, DPDT, (KB)
SW0000006	SWITCH, THERMAL, 60 C
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *
SW0000059	PRESSURE SENSOR, 0-15 PSIA, ALL SEN
WR0000008	POWER CORD, 10A(KB)

# IZS, AKIT, EXPENDABLES

## T100/M100E

(Reference 01475A)

Part Number	Description
014750000	AKIT, EXP KIT, M100A/M100E, IZS
Part Number	Description
005960000	AKIT, EXPEND, 6LBS ACT CHARCOAL
006900000	RETAINER PAD CHARCOAL, SMALL, 1-3/4"
FL0000001	FILTER, SS
FL0000003	FILTER, DFU (KB)
HW0000020	SPRING
OR0000001	ORING, 2-006VT
OR0000046	ORING, 2-019V



**Appendix C  
Warranty/Repair  
Questionnaire  
T100, M100E  
(04796F DCN6611)**



**TELEDYNE**  
ADVANCED POLLUTION INSTRUMENTATION  
Everywhereyoulook™

CUSTOMER: \_\_\_\_\_ PHONE: \_\_\_\_\_

CONTACT NAME: \_\_\_\_\_ FAX NO. \_\_\_\_\_

SITE ADDRESS: \_\_\_\_\_

MODEL SERIAL NO.: \_\_\_\_\_ FIRMWARE REVISION: \_\_\_\_\_

1. ARE THERE ANY FAILURE MESSAGES? \_\_\_\_\_

2. PLEASE COMPLETE THE FOLLOWING TABLE: (NOTE: *DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS BELOW WILL BE AVAILABLE IN YOUR INSTRUMENT*)

\*IF OPTION IS INSTALLED

Parameter	Recorded Value	Acceptable Value
RANGE	PPB/PPM	50 PPB to 20 PPM
STABIL	PPB	≤1 PPB WITH ZERO AIR
SAMP PRESS	IN-HG-A	~ 2" < AMBIENT
SAMPLE FLOW	cm <sup>3</sup> /MIN	650 ± 10%
PMT SIGNAL WITH ZERO AIR	mV	-20 TO 150 mV
PMT SIGNAL AT SPAN GAS CONC	mV PPB/PPM	0-5000 mV 0-20000 PPB
NORM PMT AT SPAN GAS CONC	mV PPB/PPM	0-5000 mV 0-20000 PPB
UV LAMP	mV	1000 TO 4800 mV
LAMP RATIO	mV	30 TO 120%
STR. LGT	PPB	≤ 100 PPB/ ZERO AIR
DARK PMT	mV	-50 TO 200 mV
DARK LAMP	mV	-50 TO 200 mV
SLOPE		1.0 ± 0.3
OFFSET	mV	< 250 mV
HVPS	V	≈ 400 – 900
RCELL TEMP	°C	50°C ± 1
BOX TEMP	°C	AMBIENT + ~ 5
PMT TEMP	°C	7°C ± 2° CONSTANT
IZS TEMP*	°C	50°C ± 1
ETEST	mV	2000 mV ± 1000
OTEST	mV	2000 mV ± 1000
Values are in the Signal I/O		
REF_4096_MV	mV	4096mv±2mv and Must be Stable
REF_GND	mV	0± 0.5 and Must be Stable

3. WHAT IS THE SAMPLE FLOW & SAMPLE PRESSURE W/SAMPLE INLET ON REAR OF MACHINE CAPPED?

SAMPLE FLOW - \_\_\_\_\_ CC      SAMPLE PRESS - \_\_\_\_\_ IN-HG-A

TELEDYNE API TECHNICAL SUPPORT

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4. WHAT ARE THE FAILURE SYMPTOMS? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. IF POSSIBLE, PLEASE INCLUDE A PORTION OF A STRIP CHART PERTAINING TO THE PROBLEM. CIRCLE PERTINENT DATA.

THANK YOU FOR PROVIDING THIS INFORMATION. YOUR ASSISTANCE ENABLES TELEDYNE API TO RESPOND FASTER TO THE PROBLEM THAT YOU ARE ENCOUNTERING.

# APPENDIX D - Interconnect Diagram

