TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
Everywhereyoulook™

Training Manual

Model T204
Nitrogen Oxides + O_3 Analyzer

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PRINCIPLES OF OPERATION

The T204 Nitrogen Oxides + Ozone Analyzer is a microprocessor-controlled instrument that determines both the concentration of ozone (O_3), and the concentrations of nitric oxide (NO), nitrogen dioxide (NO_2), and total nitrogen oxides (NOx) This section discusses the principles of operation of each sensor: nitrogen oxides in Section 0, and ozone in Section 0.

It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the reaction cell where the sample gas is exposed to ozone (O_3), initiating a chemical reaction that gives off light (hv).

The instrument measures the amount of chemiluminescence to determine the amount of NO in the sample gas.

A catalytic-reactive converter converts NO_2 in the sample gas to NO which, along with the NO present in the sample is reported as NOx. NO_2 is calculated as the difference between NOx and NO.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of NO or NO_2 are supplied and stores these results in memory. The microprocessor uses these calibration values along with the signal from the sample gas and data of the current temperature and pressure of the gas to calculate a final NOx concentration.

The concentration values and the original information from which it was calculated are stored in the unit's internal data acquisition system and are reported to the user through the front panel display or several output ports.

NITROGEN OXIDES MEASUREMENT PRINCIPLE

CHEMILUMINESCENCE CREATION IN THE T204 REACTION CELL

The T204's measures the amount of NO present in a gas by detecting the chemiluminescence that occurs when nitrogen oxide (NO) is exposed to ozone (O_3). This reaction is a two-step process:

In the first step, one molecule of NO and one molecule of O_3 collide and chemically react to produce one molecule of oxygen (O_2) and one molecule of nitrogen dioxide (NO_2). Some of the NO_2 molecules created by this reaction retain excess energy from the collision and exist in an excited state, where one of the electrons of the NO_2 molecule resides in a higher energy state than normal (denoted by an asterisk in the following equation).

$$NO + O_3 \rightarrow NO_2^* + O_2$$

The second step occurs because the laws of thermodynamics require that systems seek the lowest stable energy state available, therefore the excited NO_2 molecule

quickly returns to its ground state, releasing the excess energy. This release takes the form of a quantum of light ($h\nu$). The distribution of wavelengths for these quanta range between 600 and 3000 nm, with a peak at about 1200 nm.

Equation 1-2

$$NO_2^* \rightarrow NO_2 + h\nu_{1200nm}$$

All things being constant (temperature, pressure, amount of ozone present, etc.), the relationship between the amount of NO present in the reaction cell and the amount of light emitted from the reaction is very linear. If more NO is present, more IR light is produced. By measuring the amount of IR light produced with a sensor sensitive in the near-infrared spectrum the amount of NO present can be determined.

In addition, sometimes the excited NO_2 collides with other gaseous molecules in the reaction cell chamber or even the molecules of the reaction cell walls and transfers its excess energy to this collision partner (represented by *M* in the equation1-3) without emitting any light at all. In fact, by far the largest portion of the excited NO_2 returns to the ground state this way, leaving only a few percent yield of usable chemiluminescence.

Equation 1-3

$$NO_2^* + M \rightarrow NO_2 + M$$

The probability of a collision between the NO_2* molecule and a collision partner *M* increases proportionally with the reaction cell pressure. This non-radiating collision with the NO_2* molecules is usually referred to as *third body quenching*.

Even under the best conditions only about 20% of the NO_2 that is formed by the reaction in the excited state. In order to maximize chemiluminescence, the reaction cell is maintained at reduced pressure (thereby reducing the amount of available collision partners) and is supplied with a large, constant excess of ozone (about 3000-5000 ppm) from the internal ozone generator.

CHEMILUMINESCENCE DETECTION IN THE T204 REACTION CELL

THE PHOTO MULTIPLIER TUBE (PMT)

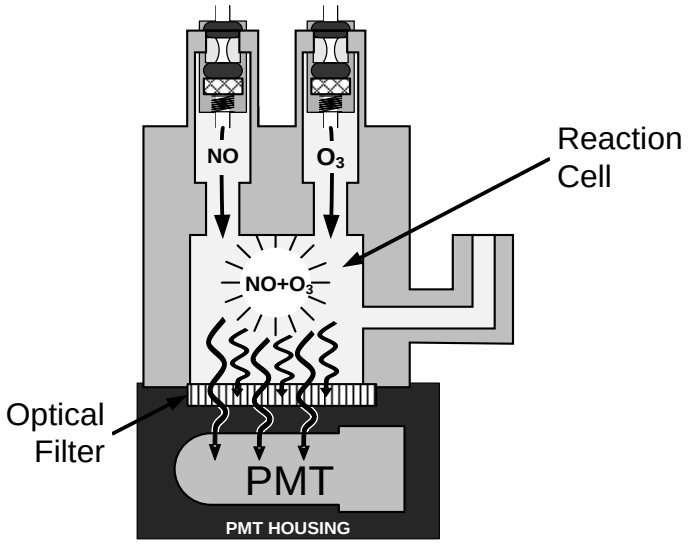
The T204 uses a special kind of vacuum tube, called a photo-multiplier tube (PMT), to detect the amount of light created by the NO and O_3 reaction in the reaction cell.

Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiplied through a sequence of similar acceleration steps (dynodes) until a useable current signal is generated. The more light present (in this case photons given off by the chemiluminescent reaction described above), the more current is produced. Therefore the more NO present in the reaction cell the more current is produced by the PMT.

The current produced by the PMT is converted to a voltage and amplified by the preamplifier board and then communicated to the T204's CPU via the A→ D converter circuitry on the analyzer.

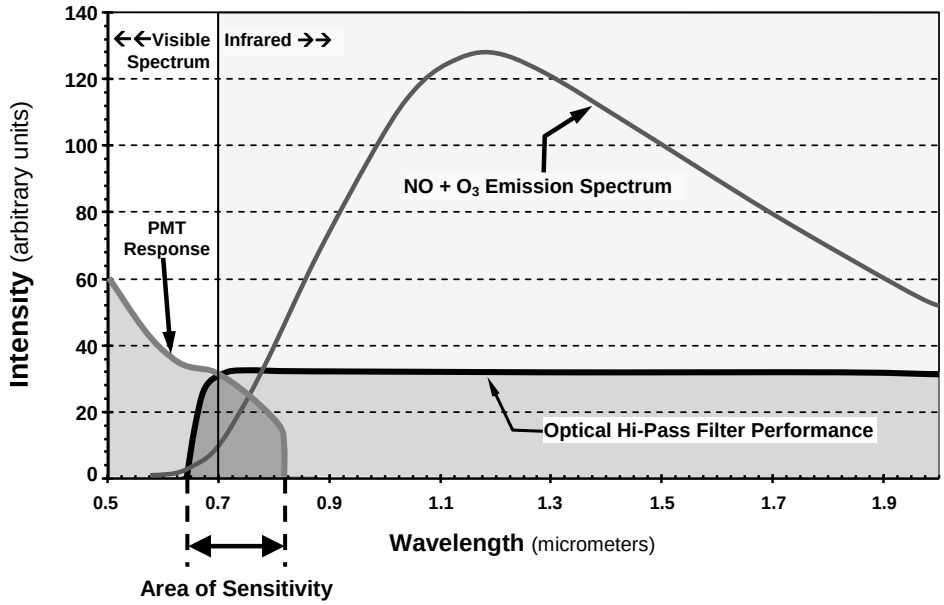
OPTICAL FILTER

A high pass optical filter, only transparent to wavelengths of light above 645nm, placed between the reaction cell and the in conjunction with the response characteristics of the PMT creates a very narrow window of wavelengths of light to which the T204 will respond.



Reaction Cell with PMT Tube and Optical Filter

The narrowness of this band of sensitivity allows the T204 to ignore extraneous light and radiation that might interfere with the T204's measurement. For instance, some oxides of sulfur can also be chemiluminescent emitters when in contact with O_3 but give off light at much shorter wavelengths (usually around 260nm to 480nm).

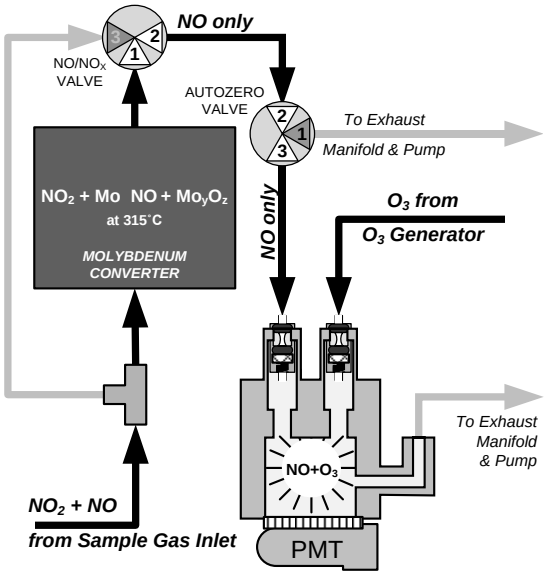


T204 NOx Sensitivity Spectrum

NOX AND NO_2 DETERMINATION

The only gas that is actually measured by the T204 is NO. NO_2, and therefore NO_x (which is defined here as the sum of NO and NO_2 in the sample gas), contained in the gas is not detected because NO_2 does not react with O_3 to create chemiluminescence.

In order to measure the concentration of NO_2, and therefore the concentration of NO_x, the T204 periodically switches the sample gas stream so that the pump pulls it through a special converter cartridge filled with molybdenum (Mo, "moly") chips that are heated to a temperature of 315°C.



NO_2→ NO Conversion

The heated molybdenum reacts with NO_2 in the sample gas and produces a NO gas and a variety of molybdenum.

$$xNO_2 + yMo \rightarrow xNO + M_yO_z \ (at\ 315°C)$$

Once the NO_2 in the sample gas has been converted to NO, it is routed to the reaction cell where it undergoes the chemiluminescence reaction described in Equation.

By converting the NO_2 in the sample gas into NO, the analyzer can measure the total NOx) content of the sample gas (i.e. the NO present + the converted NO_2 present). By switching the sample gas stream in and out of the "moly" converter every 6 - 10 seconds, the T204 analyzer is able to quasi-continuously measure both the NO and the total NOx content.

Finally, the NO_2 concentration is not directly measured but calculated by subtracting the known NO content of the sample gas from the known NOx content.

AUTO ZERO

Inherent in the operation of any PMT is a certain amount of noise. This is due to a variety of factors such as black body infrared radiation given off by the metal components of the reaction cell, unit to unit variations in the PMT units and even the constant universal background radiation that surrounds us at all times. In order to reduce this amount of noise and offset, the PMT is kept at a constant 7° C (45° F) by a Thermo-Electric Cooler (TEC).

While this intrinsic noise and offset is significantly reduced by cooling the PMT, it is not eradicated. To determine how much noise remains, once every minute for about 8 seconds the T204 diverts the sample gas flow directly to the vacuum manifold without passing the reaction cell.

During this time, only O_3 is present in the reaction cell, effectively turning off the chemiluminescence reaction. Once the chamber is completely dark, the T204 records the output of the PMT and keeps a running average of these **AZERO** values. This average offset value is subtracted from the raw PMT readings while the instrument is measuring NO and NOx to arrive at an Auto Zero corrected reading.

OZONE MEASUREMENT PRINCIPLE

The detection of ozone molecules is based on absorption of 254 nm UV light due to an internal electronic resonance of the O_3 molecule. The Model 465L uses a mercury lamp constructed so that a large majority of the light emitted is at the 254nm wavelength. Light from the lamp shines down a hollow quartz tube that is alternately filled with sample gas, then filled with gas scrubbed to remove ozone. The ratio of the intensity of light passing through the scrubbed gas to that of the sample forms a ratio I/I_O. This ratio forms the basis for the calculation of the ozone concentration.

The Beer-Lambert equation, shown below, calculates the concentration of ozone from the ratio of light intensities.

$$C_{O_3} = -\frac{10^9}{\alpha \times \ell} \times \frac{\mathrm{T}}{273^o \mathrm{K}} \times \frac{29.92 inHg}{\mathrm{P}} \times \ln \frac{\mathrm{I}}{\mathrm{I}_o}$$

Where:

I = Intensity of light passed through the sample

I_o = Intensity of light through sample free of ozone

α = absorption coefficient

ℓ = path length

C_{O_3} = concentration of ozone in ppb

T = sample temperature in degrees Kelvin

P = pressure in inches of mercury

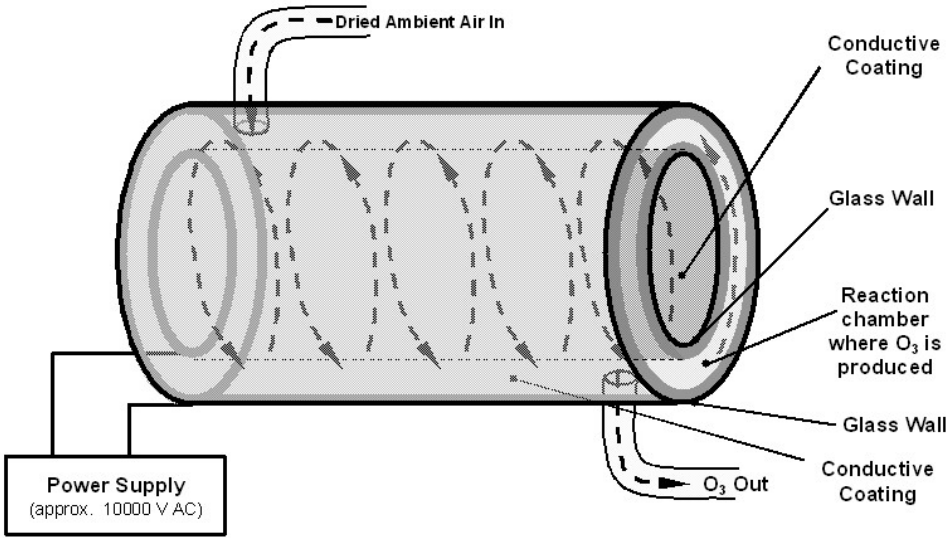
As can be seen the concentration of ozone depends on more than the intensity ratio. Temperature and pressure influence the density of the sample. The density changes the number of ozone molecules in the absorption tube which impacts the amount of light removed from the light beam. These effects are addressed by directly measuring temperature and pressure and including their actual values in the calculation. The absorption coefficient is a number that reflects the inherent ability of ozone to absorb 254 nm light. Most current measurements place this value at 308 cm^{-1} atm^{-1} at STP. The value of this number reflects the fact that ozone is a very efficient absorber of UV radiation which is why stratospheric ozone protects the life forms lower in the atmosphere from the harmful effects from solar UV radiation. Lastly, the absorption path length determines how many molecules are present in the column of gas in the absorption tube.

The intensity of light is converted into a voltage by a high resolution A/D (analog-to-digital) converter. The digitized signal and other variables are used by the CPU to compute the concentration using the above formula.

About every 2.5 seconds the 465L completes a measurement cycle consisting of a 1 second wait period for the sample tube to flush, followed by a 150 ms measurement of the UV light intensity to obtain I. The sample valve is switched to admit scrubbed sample gas for 1 second, followed by a 150 ms measurement of the UV light intensity to obtain I_O. Measurement of the I_O every 2.5 seconds eliminates instrument drift due to changing intensity of the lamp caused by aging and dirt.

O_3 Generator

The M200E uses a corona discharge (CD) tube for creating its O_3. Corona discharge generation is capable of producing high concentrations of ozone efficiently and with low excess heat. Although there are many cell designs, the fundamental principle remains the same.



Ozone Generator Principle

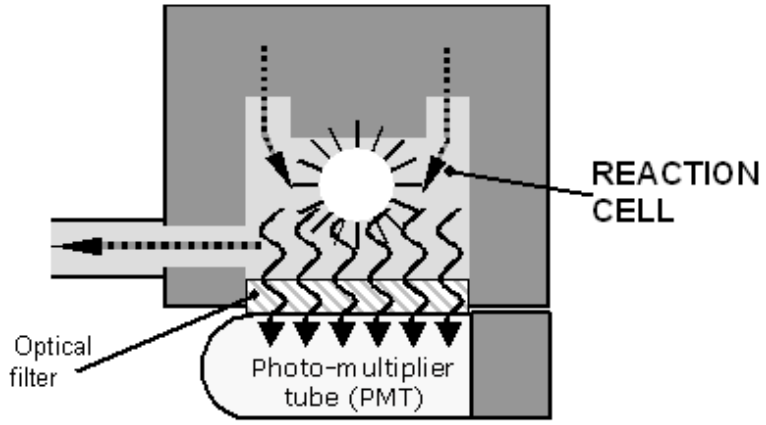
The M200E utilizes a dual-dielectric design. This method utilizes a glass tube with hollow walls. The outermost and innermost surfaces are coated with electrically conductive material. The air flows through the glass tube between the two conductive coatings, in effect creating a capacitor with the air and glass acting as the dielectric. The layers of glass also separate the conductive surfaces from the air stream to prevent reaction with the O_3. As the capacitor charges and discharges, electrons are created and accelerated across the air gap and collide with the O_2 molecules in the air stream splitting them into elemental oxygen. Some of these oxygen atoms recombine with O_2 to form O_3.

The quantity of ozone produced is dependent on factors such as the voltage and frequency of the alternating current applied to the CD cells. When enough high-energy electrons are produced to ionize the O_2 molecules, a light emitting, gaseous plasma is formed, which is commonly referred to as a corona, hence the name corona discharge generator.

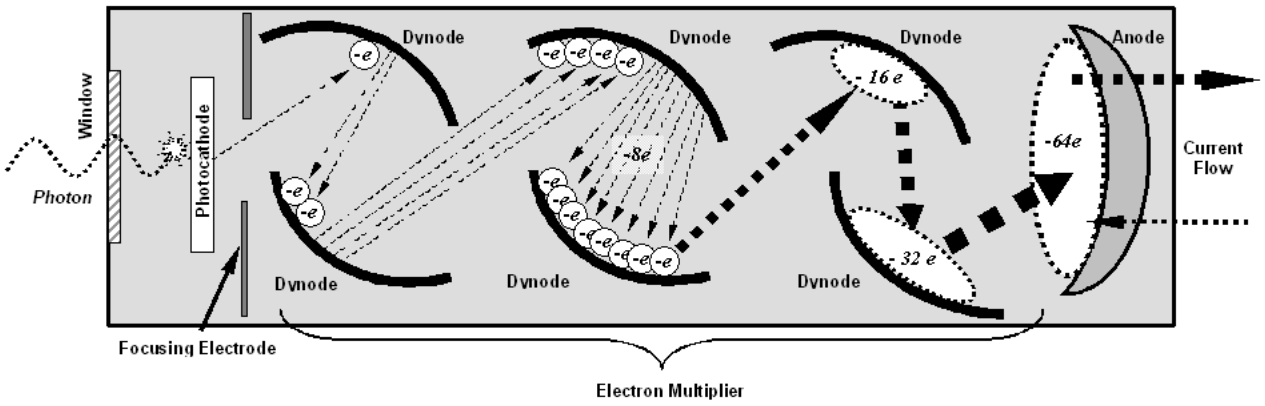
The Photo Multiplier Tube

The M200E uses a photo-multiplier tube (PMT) to detect the amount of light created by the NO and O_3 reaction in the reaction cell.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by an applied high voltage and multiply through a sequence of such acceleration steps (dynodes) until a useable current signal is generated. This current, which increases or decreases with the amount of detected light, is converted to a voltage and amplified by the preamplifier board and then reported to the motherboard's analog inputs.



Reaction Cell with PMT Tube



Basic PMT Design and Functionality

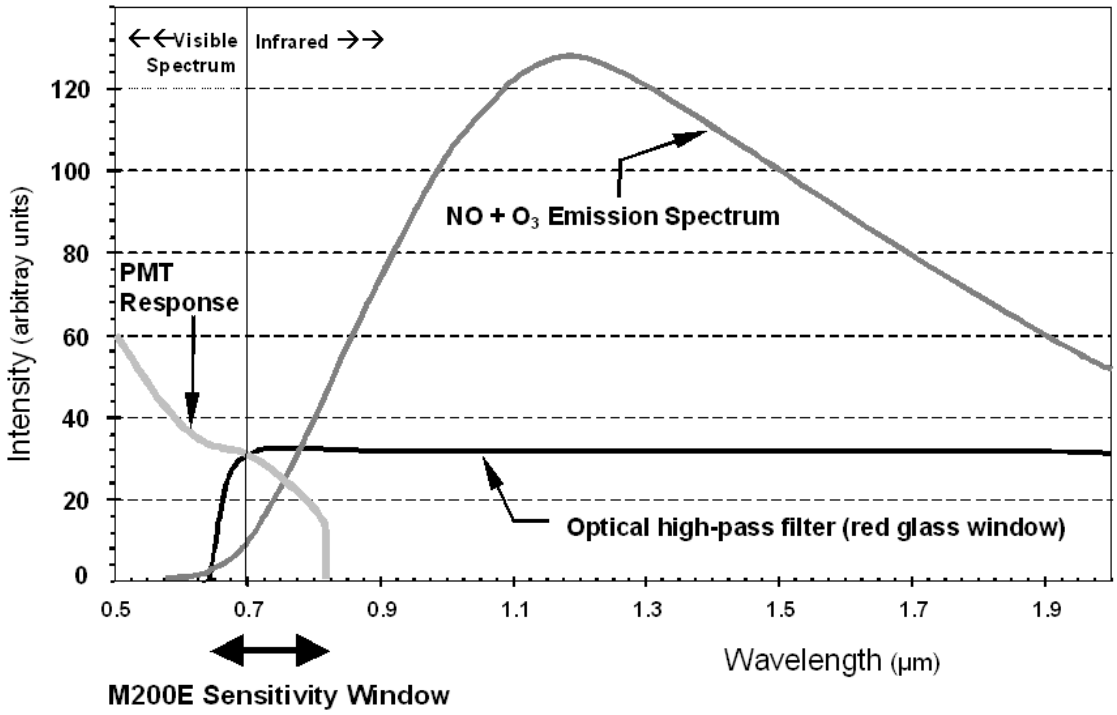
A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater is the number of electrons emitted from each dynode of the electron multiplier, making the PMT more sensitive and responsive to small variations in light intensity but also increases random noise (dark noise). The gain voltage of the PMT used in the M200E is usually set between 450 V and 900 V. This parameter is viewable through the front panel as test function HVPS and usually does not need to be changed unless the PMT or the HVPS itself is changed This can be changed by performing a factory calibration upon the analyzer.

The PMT is housed inside the sensor module assembly. 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).

Optical Filter

Another critical component in the method by which your M200E detects chemiluminescence is the optical filter that lies between the reaction cell and the PMT. This filter is a high pass filter that is only transparent to wavelengths of light above 665ηm. In conjunction with the response characteristics of the PMT, this filter creates a very narrow window of wavelengths of light to which the M200E will respond.

The narrow band of sensitivity allows the M200E to ignore extraneous light and radiation that might interfere with the M200E's measurement. For instance, some oxides of sulfur can also undergo chemiluminescence when in contact with O_3 but emit light at shorter wavelengths (Usually around 260ηm to 480ηm).

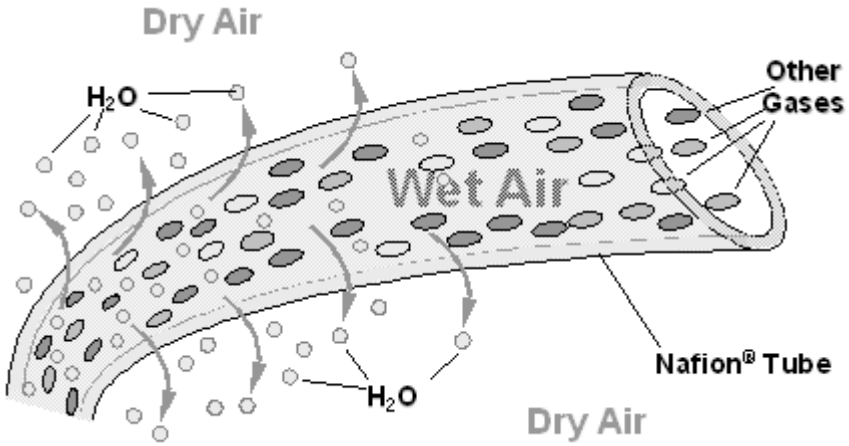


M200E Sensitivity Spectrum

Perma Pure® Dryer

The air supplied to the O_3 generation system needs to be as dry as possible. Normal room air contains some amount of water vapor, which greatly diminishes the yield of ozone produced by the ozone generator. Also, water can react with other chemicals inside the O_3 generator to produce chemicals that damage the optical filter located in the reaction cell, such as ammonium sulfate or highly corrosive nitric acid.

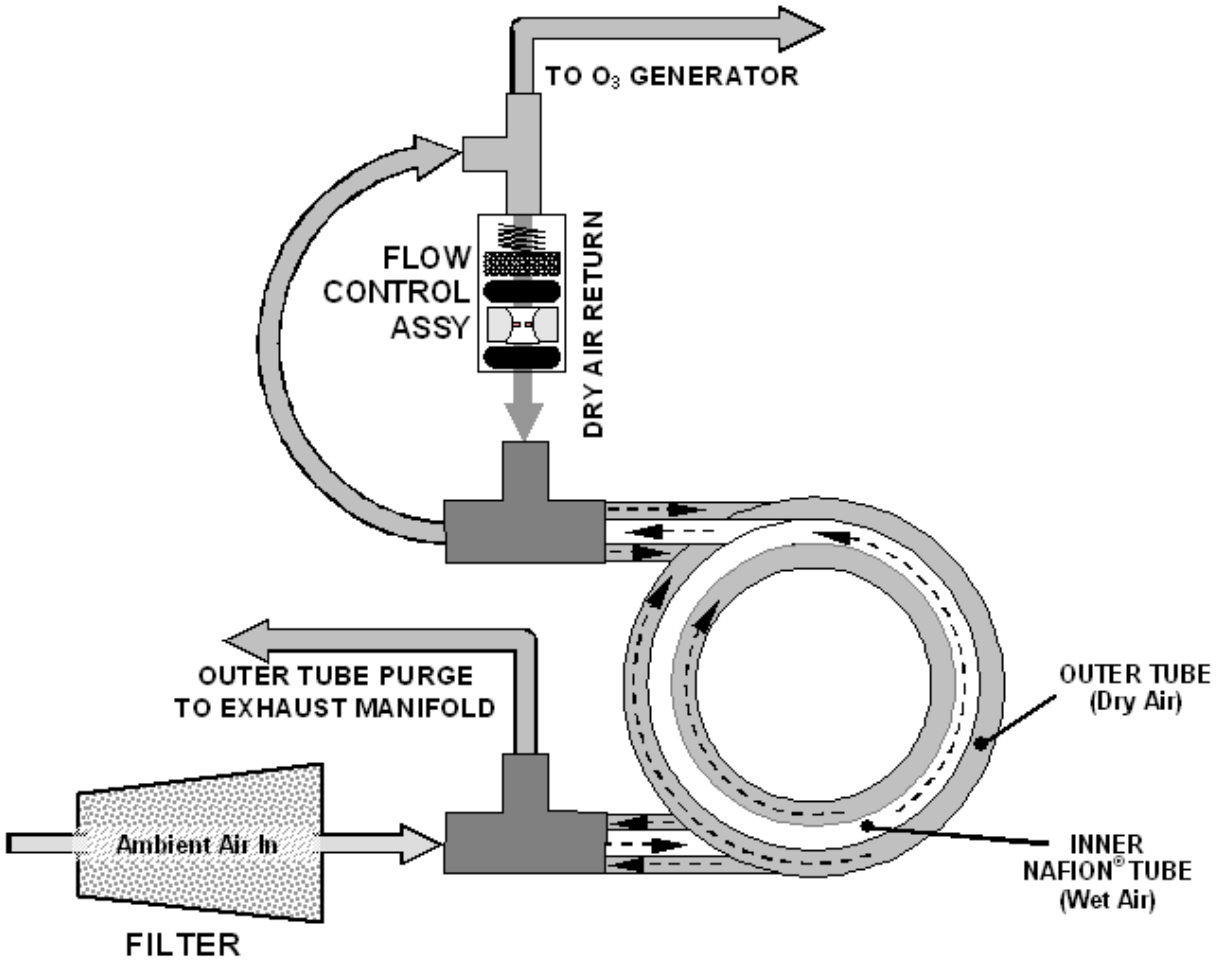
To accomplish this task the M200E uses a Perma Pure® single tube permeation dryer. The dryer consists of a single tube of Nafion®, a co-polymer similar to Teflon® that absorbs water very well but not other chemicals. The Nafion® tube is mounted within an outer, flexible plastic tube. As gas flows through the inner Nafion® tube, water vapor is absorbed into the membrane walls. The absorbed water is transported through the membrane wall and evaporates into the dry, purge gas flowing through the outer tube, countercurrent to the gas in the inner tube.



Semi-Permeable Membrane Drying Process

This process is called per-evaporation and is driven by the humidity gradient between the inner and outer tubes as well as the flow rates and pressure difference between inner and outer tubing. Unlike micro-porous membrane permeation, which transfers water through a relatively slow diffusion process, per-evaporation is a simple kinetic reaction. Therefore, the drying process occurs quickly, typically within milliseconds. The first step in this process is a chemical reaction between the molecules of the Nafion® material and water, other chemical components of the gases to be dried are usually unaffected. The chemical reaction is based on hydrogen bonds between the water molecule and the Nafion material. Other small polar gases that are capable of hydrogen bonds can be absorbed this way, too, such as ammonia (NH_3) and some low molecular amines. The gases of interest, NO and NO_2, do not get absorbed and pass through the dryer unaltered when used on the sample side of the analyzer.

To provide a dry purge gas for the outer side of the Nafion tube, the M200E returns some of the dried air from the inner tube to the outer tube. When the analyzer is first started, the humidity gradient between the inner and outer tubes is not very large and the dryer's efficiency is low at first but improves as this cycle reduces the moisture in the sample gas and settles at a minimum humidity.



M200E Perma Pure® Dryer

Just like on startup, if the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the humidity gradient to become large enough for the Perma Pure® Dryer to adequately dry the air. In this case, called a cold start, the O_3 generator is not turned on for 30 minutes. When rebooting the instrument within less than 30 minutes of power-down, the generator is turned on immediately.

The Perma Pure® Dryer used in the M200E is capable of adequately drying ambient air to a dew point of ≤ -5˚C (~4000 ppm residual H_2O) at a flow rate of 1 standard liter per minute (slpm) or down to ≤ -15˚C (~1600 ppm residual H_2O) at 0.5 slpm. The Perma Pure® Dryer is also capable of removing ammonia from the sample gas up to concentrations of approximately 1 ppm.

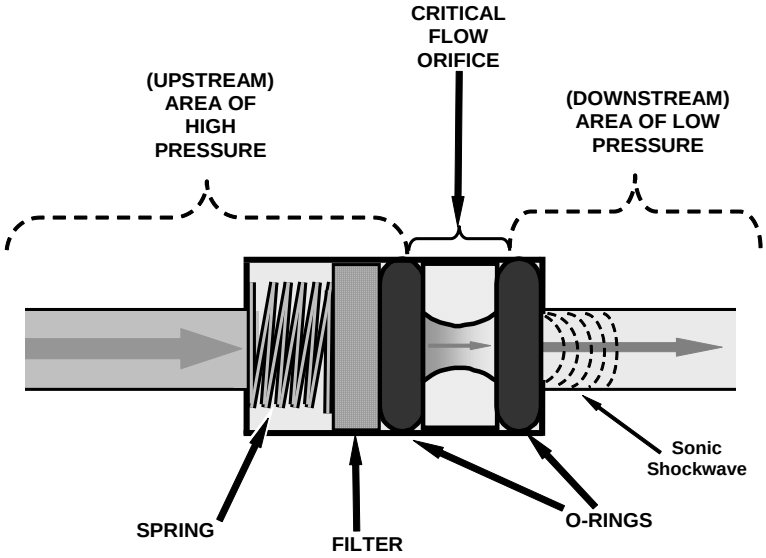
Critical Flow Orifices

In order to maintain constant flow rates for both the O_3 supply air and the sample gas, the M200E uses a variety of critical-orifice flow control assemblies located at these places in the pneumatic system of the instrument:

Reaction cell, sample inlet
Reaction cell, ozone inlet
Vacuum manifold, autozero exit
Vacuum manifold, IZS purge (if installed)
Permapure ozone air dryer, purge flow control
Permapure sample or combo dryer, purge flow control (if installed)

The most important component of each flow control assembly is the critical flow orifice. Critical flow orifices are a simple means to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. By restricting the flow of gas through the orifice, a pressure differential is created. This pressure differential, created by the analyzer's external 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 of the gas flowing 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 and remains constant, regardless of any further pressure difference. As long as that ratio stays at least 2:1, the gas flow rate is unaffected by fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out at the downstream exit of the critical flow orifice.



Flow Control Assembly & Critical Flow Orifice

The actual flow rate of gas through the orifice depends entirely on the size and shape of the aperture in the orifice and the upstream pressure. The larger the hole, the more gas molecules pass through the orifice. The flow rate of the gas is unaffected by small degradations in pump efficiency due to age as long as the 2:1 pressure difference is maintained.

T204 Gas Flow Rates

Location	Purpose	Orifice Diameter	**Flowrate** (nominal)
Sample gas inlet of reaction cell	Controls rate of flow of sample gas into the reaction cell.	0.010" (10mil)	500 cm³/min
O_3 supply inlet of reaction cell.	Controls rate of flow of ozone gas into the reaction cell.	0.004" (4mil)	80 cm³/min
Dry air return of Perma Pure® dryer	Controls flow rate of dry air return / purge air of the dryer.	0.004" (4mil)	80 cm³/min
Vacuum manifold, auto-zero port.	Controls rate of sample gas flow when bypassing the reaction cell during the auto-zero cycle.	0.010" (10mil)	500 cm³/min
Vacuum manifold, IZS exhaust port	Controls rate of flow of zero purge gas through the IZS option (when installed and enabled) when inactive.	0.003" (3mil)	50 cm³/min
O3 Bench	Controls rate of flow thru ozone bench.	0.012* (12mil)	800 cm³/min

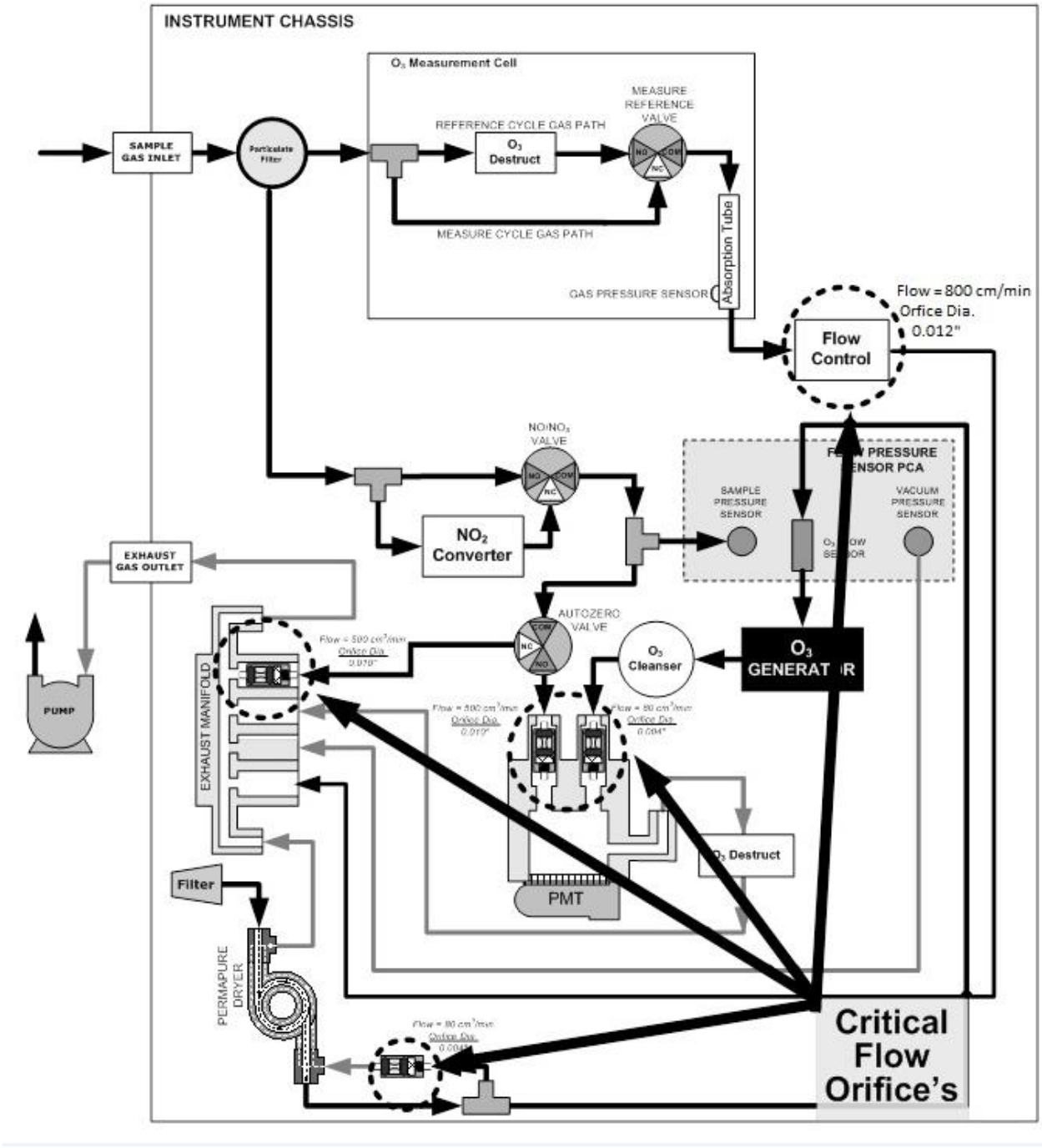
Note that the diameter of the critical orifice may change with temperature because of expansion of the orifice material (ruby) and, hence, the most critical flow orifices in the M200E are maintained at a constant temperature inside the reaction cell. These are the sample and O_3 flows. The table above shows the flow rates for each of the critical flow orifices of the M200E.

In addition to controlling the gas flows, the two critical flow orifices at the inlets of the reaction cell also maintain a low pressure inside the reaction cell. This effectively reduces the number of molecules in the chamber and therefore increases the chemiluminescence yield as the likelihood of third body quenching is reduced. The M200E sensitivity reaches a peak at about 2 in-Hg-A, below which the sensitivity drops due to a low number of molecules and decreased yield in the chemiluminescence reaction.

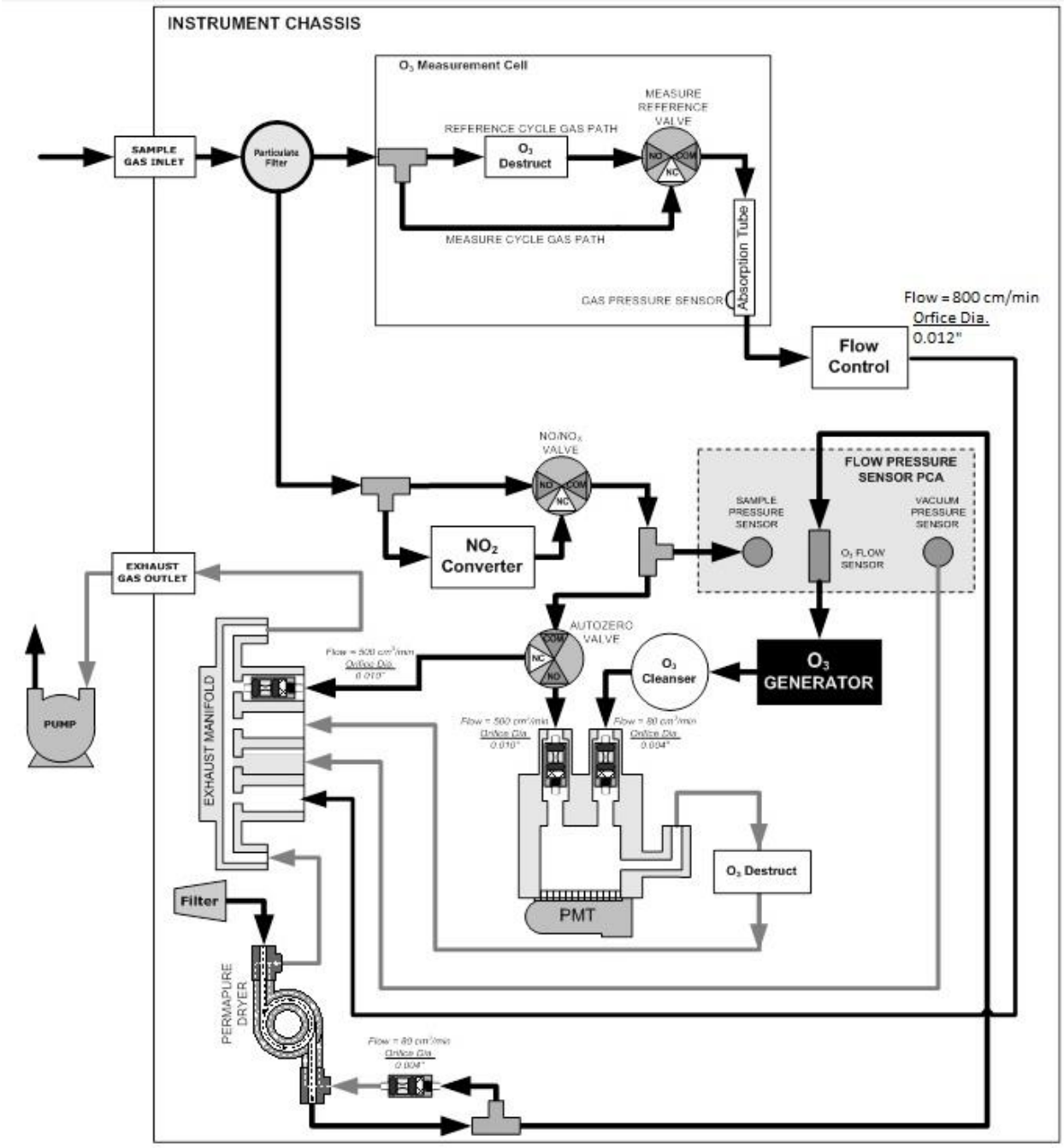
The other components of the flow control assemblies are:

- A sintered stainless steel filter, which prevents particulates from entering the reaction cell and potentially plugging the orifice.
- Two o-rings are located before and after the critical flow orifice to seal the gap between the walls of the assembly housing and the critical orifice, thus forcing all gas through the orifice opening.
- A spring applies mechanical force to form the seal between the o-rings, the critical flow orifice and the assembly housing and to prevent the components from floating up and turning on sudden pressure drops.

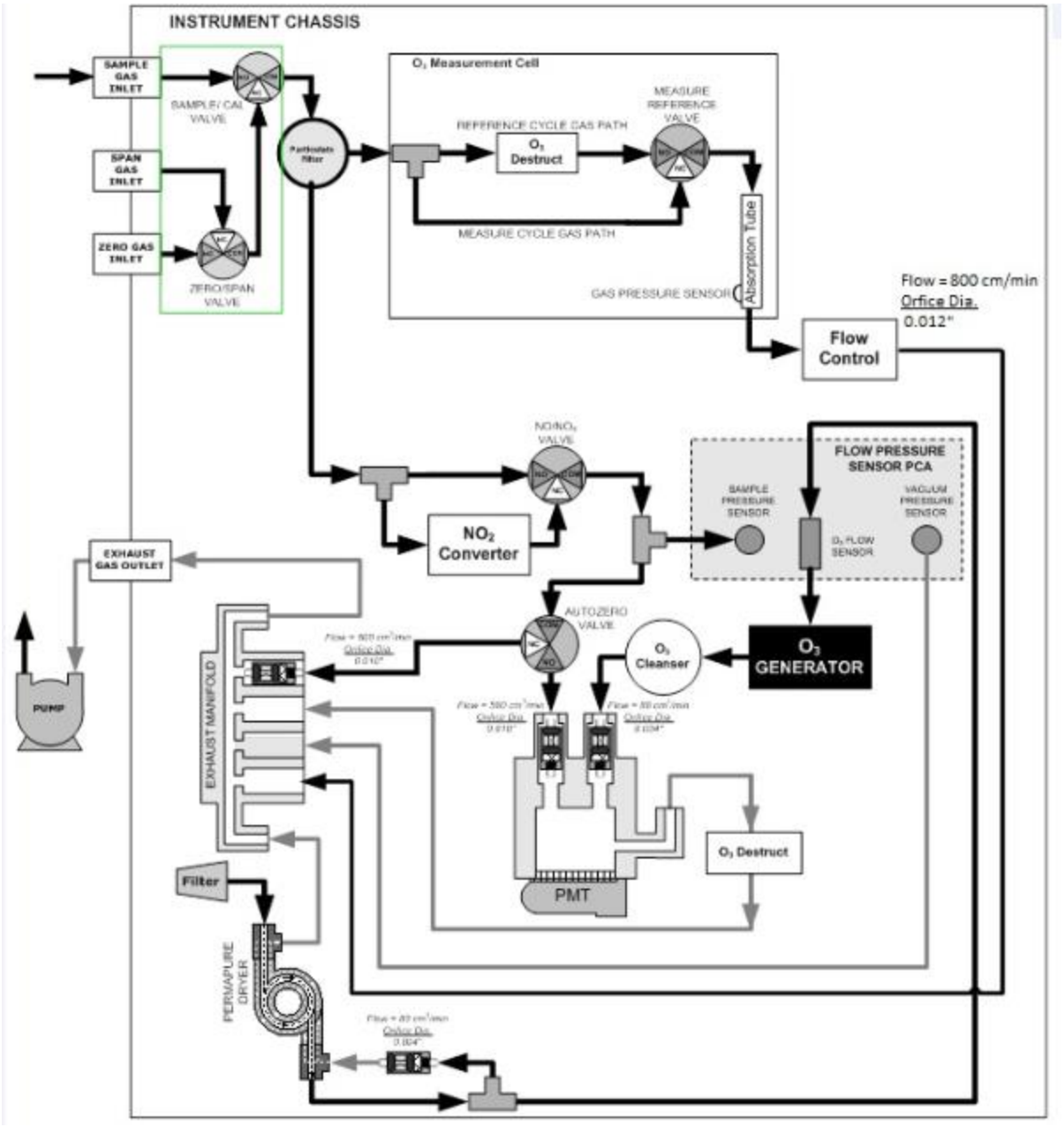
PNEUMATICS



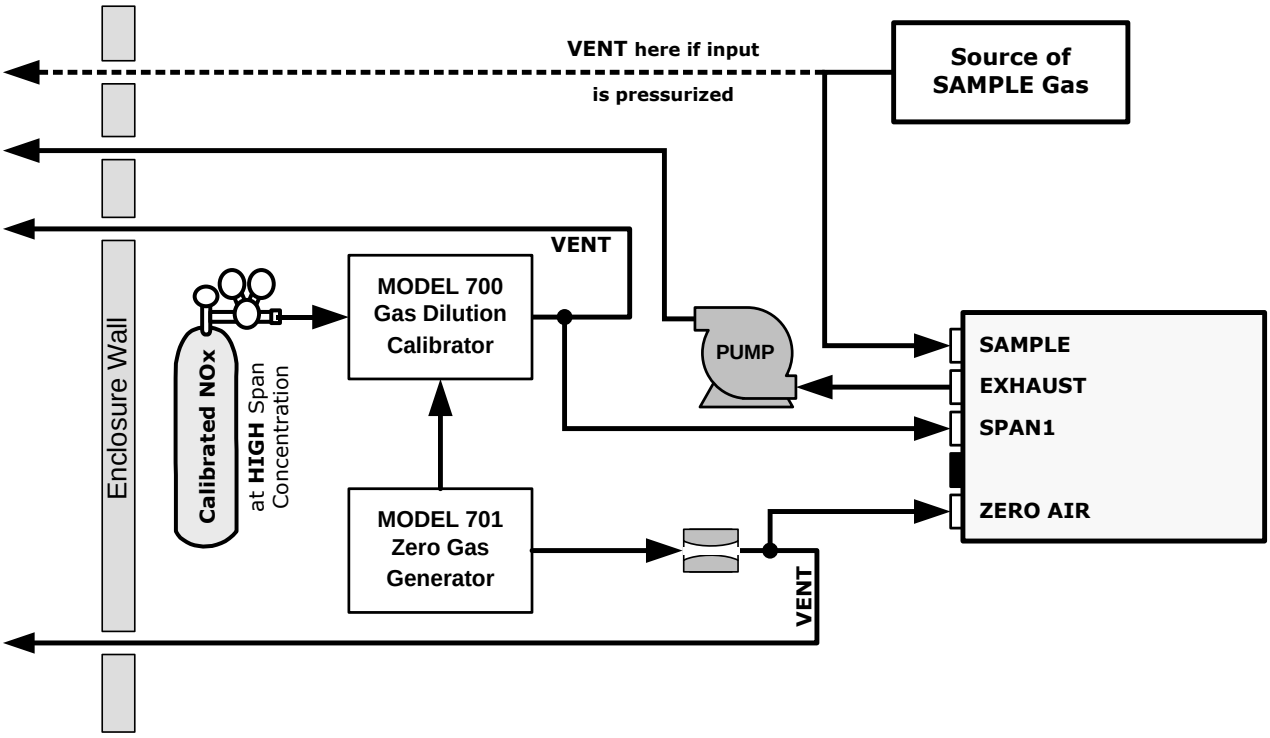
Location of Flow Control Assemblies & Critical Flow Orifices



Pneumatics, Basic Configuration

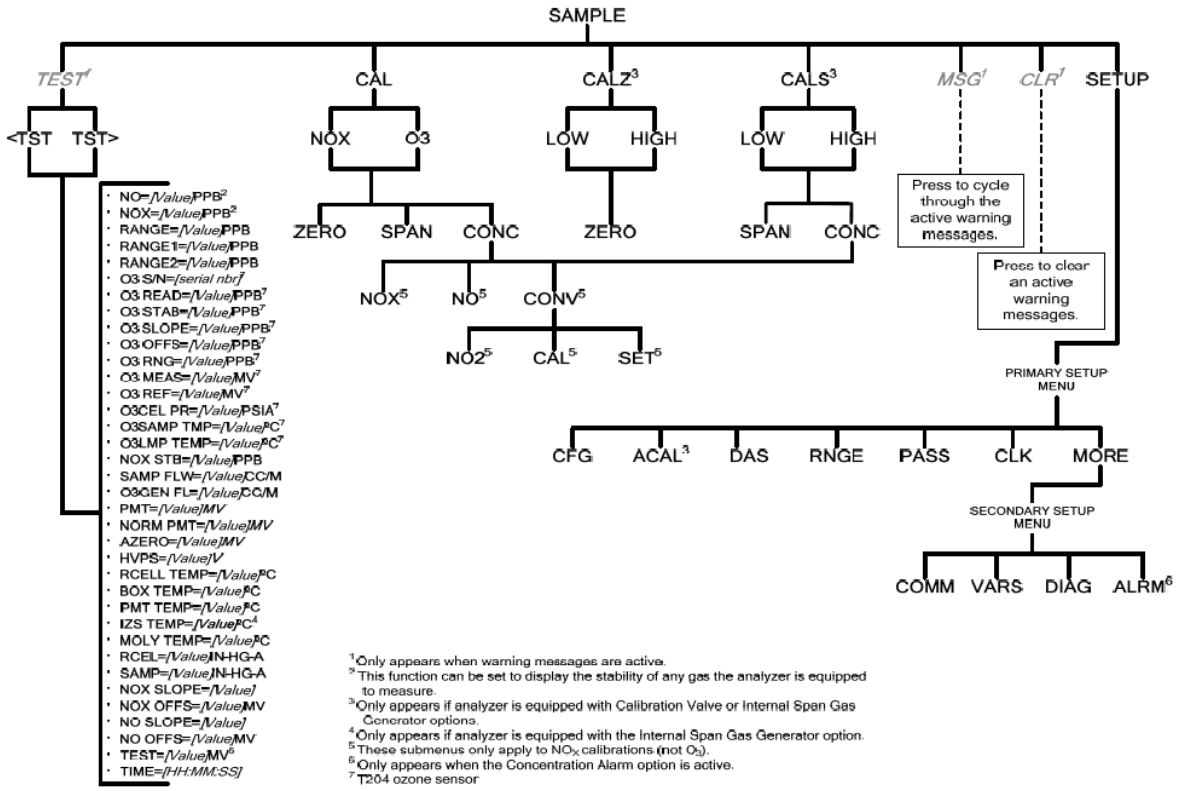


Pneumatics with Zero/Span Valves OPT 50A



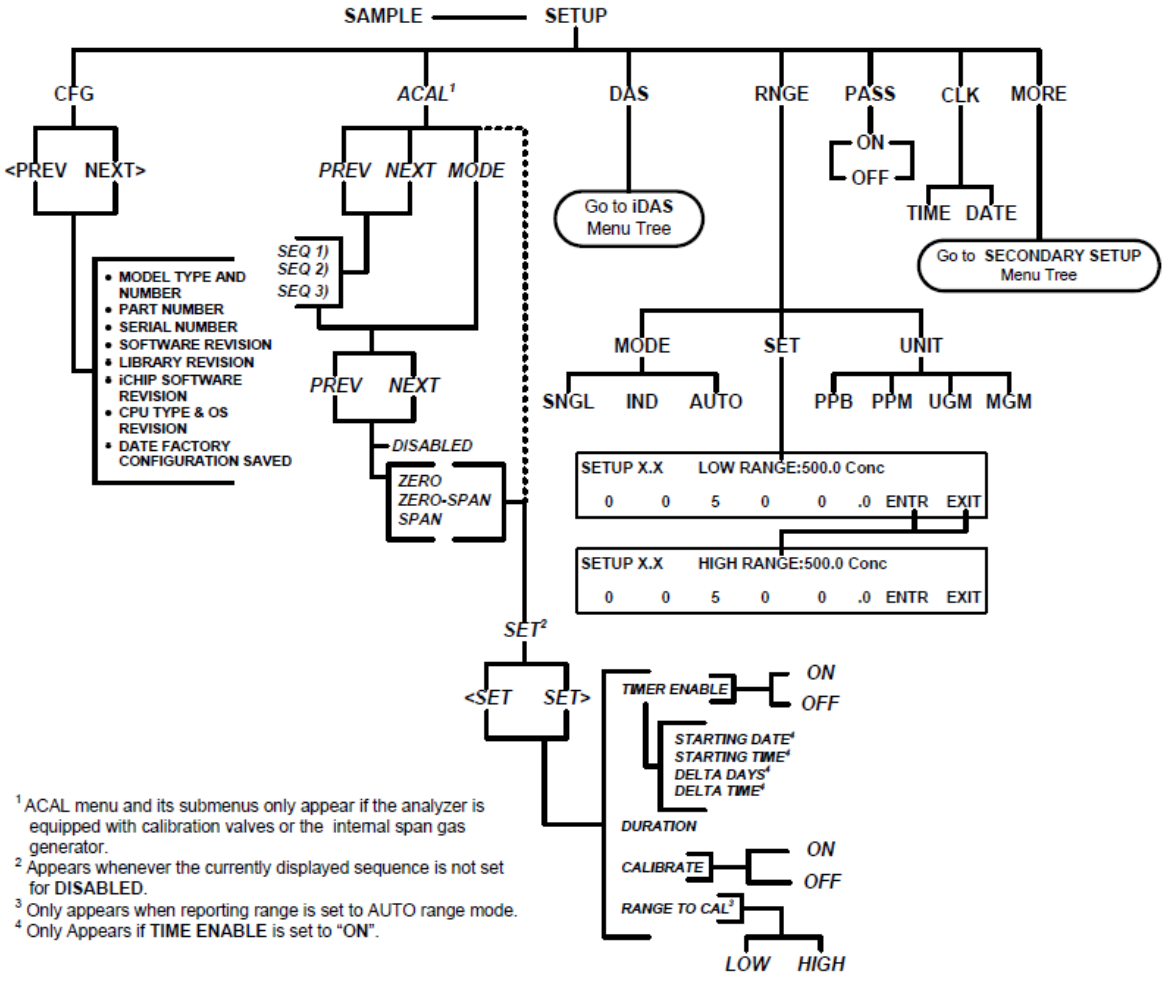
Gas Line Connections for T204 with Z/S Valves Option (OPT 50A)

MENU STRUCTURE



[1] Only appears when warning messages are active.
[2] This function can be set to display the stability of any gas the analyzer is equipped to measure.
[3] Only appears if analyzer is equipped with Calibration Valve or Internal Span Gas Generator options.
[4] Only appears if analyzer is equipped with the Internal Span Gas Generator option.
[5] These submenus only apply to NO_X calibrations (not O_3).
[6] Only appears when the Concentration Alarm option is active.
[7] T204 ozone sensor

Figure A-1: Basic Sample Display Menu



[1] ACAL menu and its submenus only appear if the analyzer is equipped with calibration valves or the internal span gas generator.
[2] Appears whenever the currently displayed sequence is not set for **DISABLED**.
[3] Only appears when reporting range is set to AUTO range mode.
[4] Only Appears if **TIME ENABLE** is set to "**ON**".

Figure A-2: Primary Setup Menu (Except DAS)

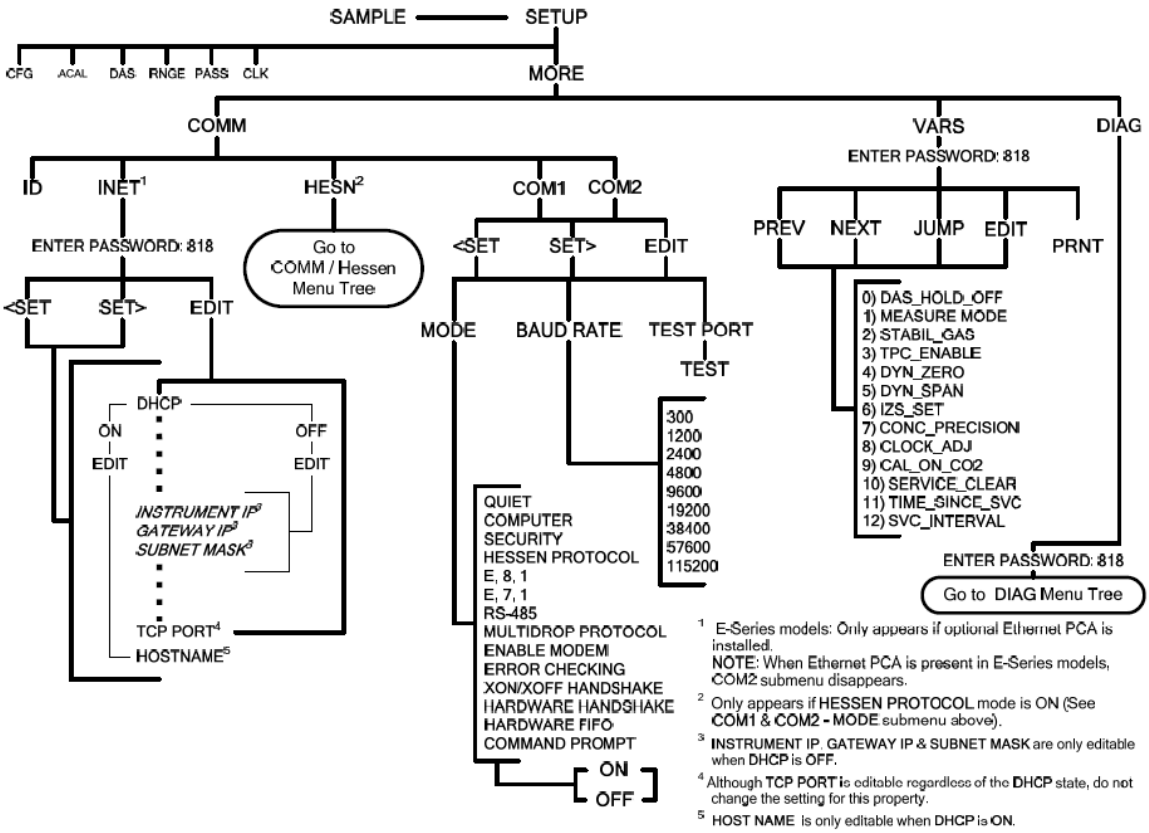


Figure A-3: Secondary Setup Menu (COMM & VARS)

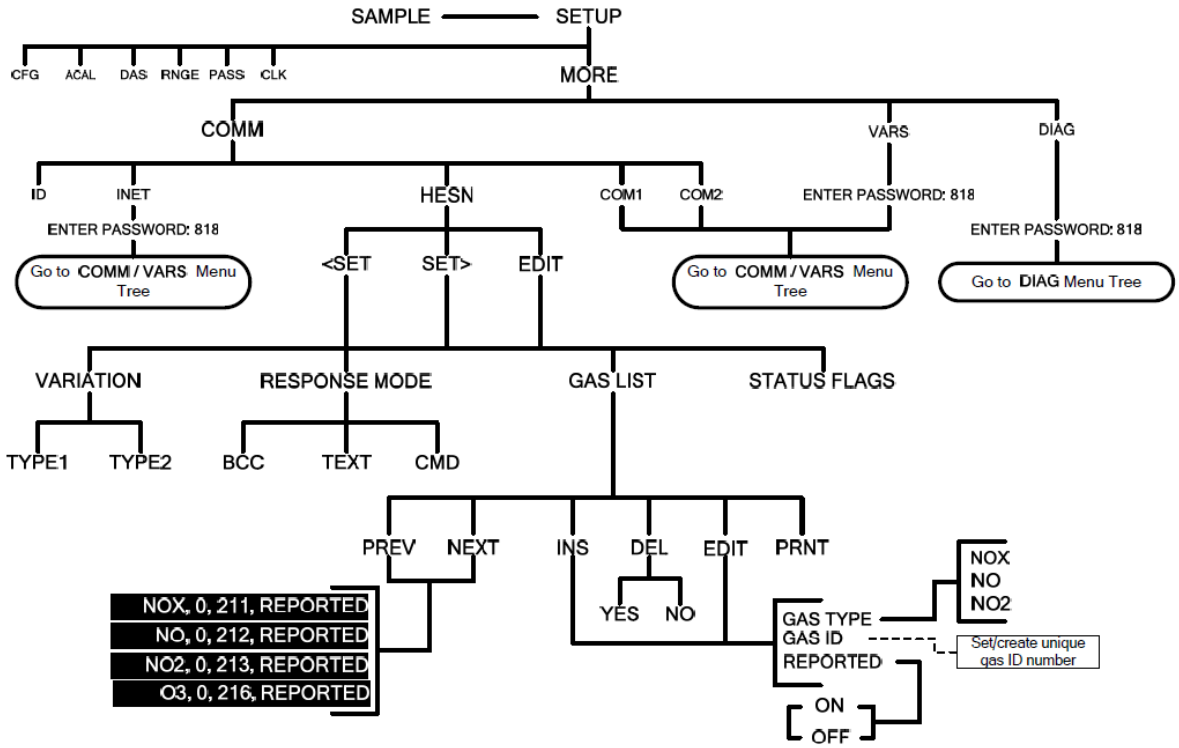


Figure A-4: Secondary Setup Menu (HESSEN)

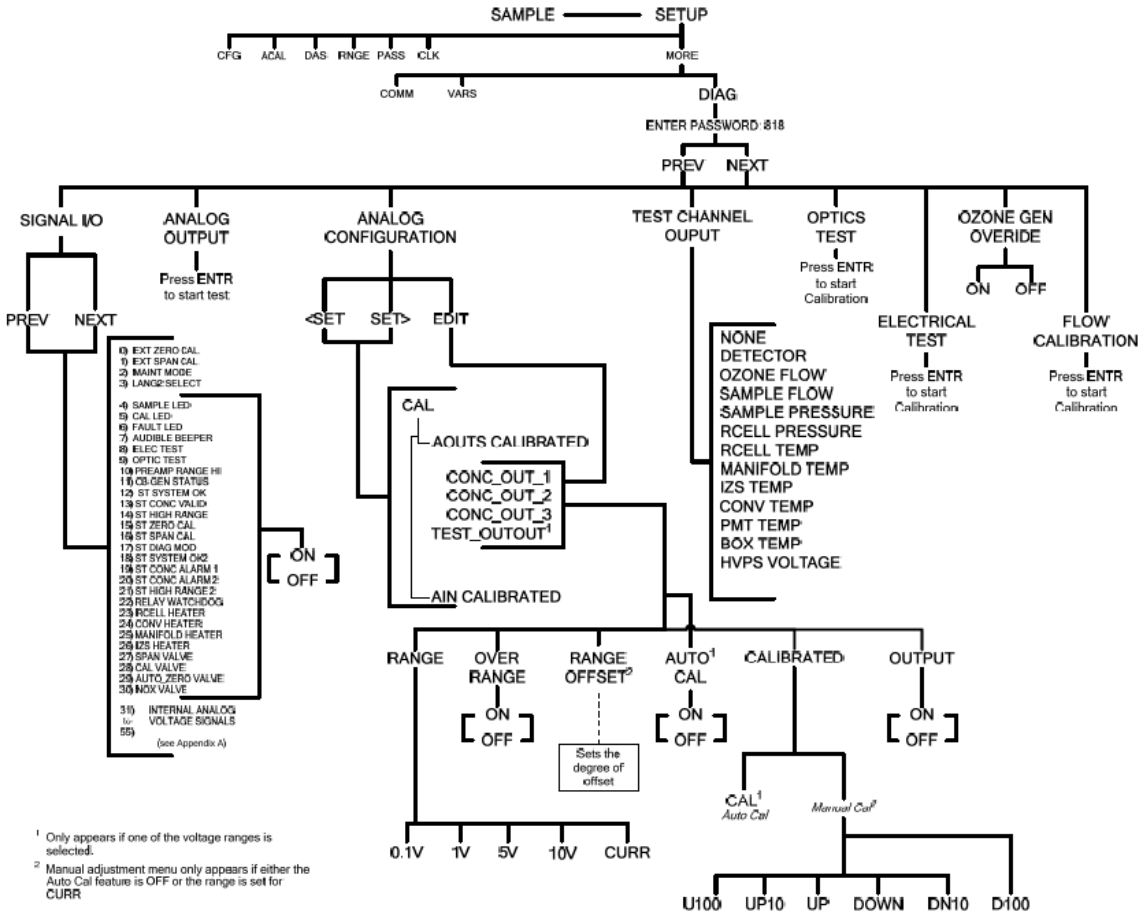


Figure A-5: Secondary Setup Menu (DIAG)

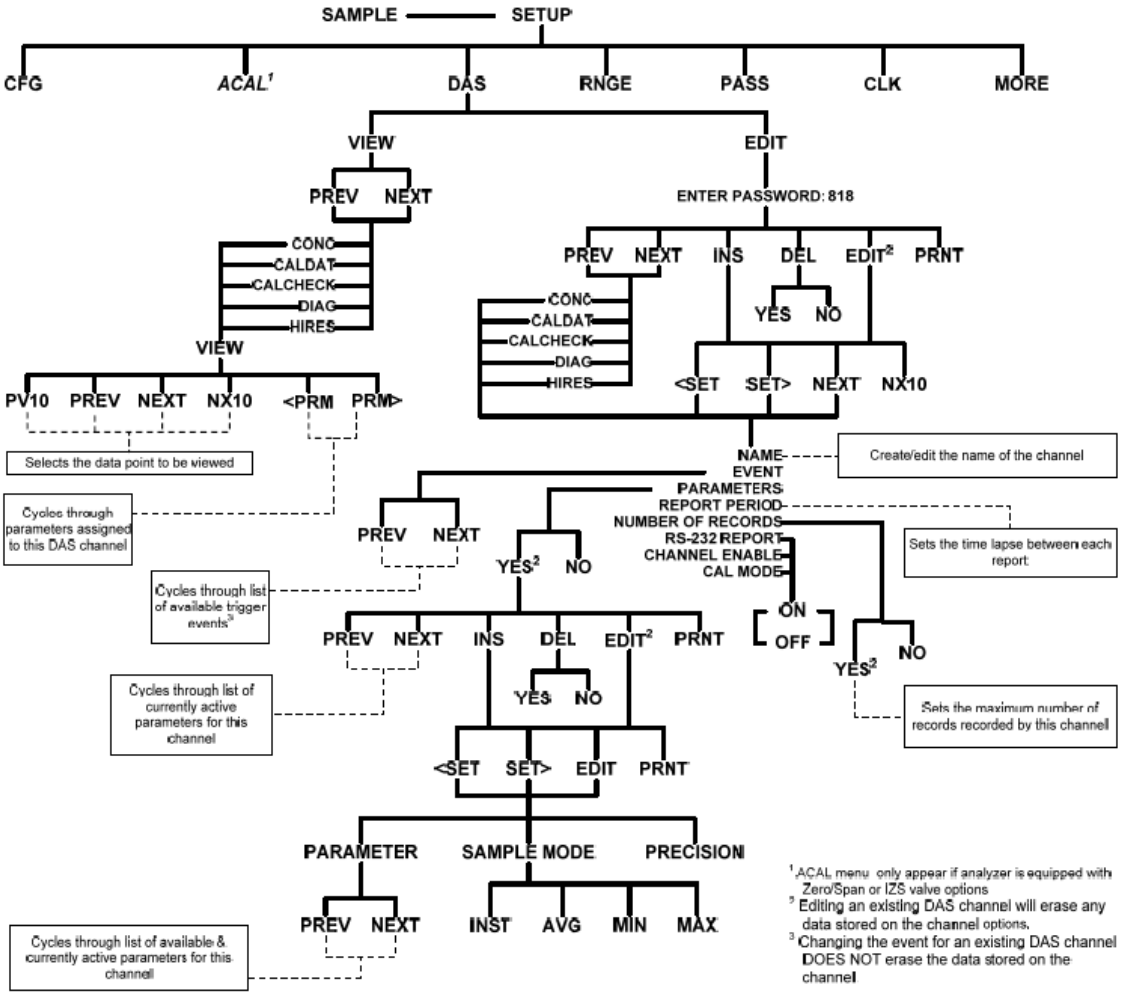


Figure A-6: Internal Data Acquisition (DAS) Menu

CALIBRATION PROCEDURES

HOW TO PERFORM A MANUAL DAC CALIBRATION

1. From the main menu press SETUP-MORE-DIAG-ENTR-NEXT until ANALOG I/O CONFIGURATION press ENTR.
2. Press SET> until it reads read A/IN CALIBRATED:
3. Press CAL to calibrate the analog inputs.
4. Press <SET until the top line reads CONC_OUT_1 and press EDIT
    a. If this is the output voltage you desire then go to step 7
    b. If this voltage is incorrect press EDIT and change to the output voltage desired, press ENTR and go to step 7.
5. Press EDIT, Press SET>. The top line should read CONC_OUT_1: REC OFFSET: 0mv
    a. If you don't want a recorder offset go to step 8.
    b. If you want a recorder offset press EDIT. Enter the OFFSET value and press ENTR. Go to step 8.
6. Press SET>. The top line should read CONC_OUT_1: AUTO CAL: ON
    a. If this says AUTO CAL ON press EDIT and turn it OFF.
    b. If this says AUTO CALL OFF go to step 9.
7. Press SET>. The top line should read CONC_OUT_1: CALIBRATED: YES
8. Now place your meter on pins 1 and 2 on the rear panel analog output connector and set your meter to read mvDC.
9. Press CAL on the front panel.
10. You should have some DN and UP buttons. And the top line should be say ZERO ADJUST or something similar.
11. The output on the meter should be as close as possible to 0mV ±0.3mV.
    a. If it is not then press DN or UP until the meter reads as close as possible to 0mv
    b. If it does go to step 14
12. Press ENTR.
13. The top line should now say GAIN ADJUST and you should have DN and UP buttons again. The meter should now read your full-scale voltage (i.e. 1V, 5V, 10V) you will have to change the range on the meter to read Volts instead of Mili-volts.
14. Press the DN and UP buttons until the output on the meter reads your full-scale voltage ±1mV.
15. Press ENTR
16. That channel is now calibrated.
17. Do this for all channels and ensure that you move the meter on the output connector to the proper pins.

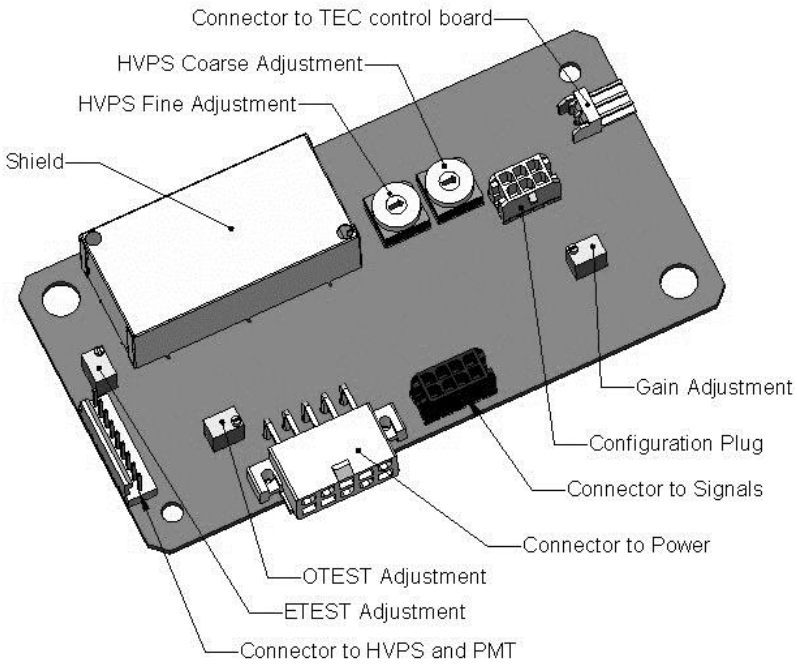
CURRENT OUTPUT

1. From the main menu press SETUP-MORE-DIAG-ENTR-NEXT until ANALOG I/O CONFIGURATION press ENTR.
2. Press SET> 5 times.
3. The top line should read A/IN CALIBRATED: YES
4. Press CAL to calibrate the analog inputs.
5. Press <SET 4 times.
6. The top line should read CONC_OUT_1: CURRENT
    a. If you desire Current output then go to step 7
    b. If you do not desire Current output press EDIT and change to the output voltage desired, press ENTR and follow the steps in the Voltage Output procedure.
7. Press EDIT, Press SET>. The top line should read CONC_OUT_1: AUTO CAL: ON
    a. If this says AUTO CAL ON press EDIT and turn it OFF.
    b. If this says AUTO CALL OFF go to step 8.
8. Press SET>. The top line should read CONC_OUT_1: CALIBRATED: YES
9. Now place your meter on pins 1 and 2 on the rear panel analog output connector and set your meter to read mA.
10. Press CAL on the front panel.
11. You should have some DN and UP buttons. And the top line should be say ZERO ADJUST or something similar.
12. The output on the meter should be as close as possible to 0ma ±0.01ma (if 0-20ma output), 4ma ±0.01ma (if 4-20ma output).
    a. If not then press DN or UP until the meter reads as close as possible to 0ma or 4ma.
    b. If it does go to step 13
13. Press ENTR.
14. The top line should now say GAIN ADJUST and you should have DN and UP buttons again. The meter should now read your full-scale current output 20ma.
15. If it doesn't press the DN and UP buttons until the output on the meter reads your full-scale current output of 20ma ±0.01ma.
16. Press ENTR
17. That channel is now calibrated.
18. Do this for all remaining channels that contain the Current option and ensure that you move the meter on the output connector to the proper pins for that channel.

Factory Calibration for a T204

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.

- Let the instrument run for one hour to stabilize all. This is required to ensure proper scaling of the **NORM PMT** value.
- Perform a full zero calibration using zero air.
- Locate the preamp board.
- Locate the following components On the preamp board
    - HVPS coarse adjustment switch (Range 0-9, then A-F)
    - HVPS fine adjustment switch (Range 0-9, then A-F)
    - Gain adjustment potentiometer (Full scale is 12 turns)



Pre-Amplifier Board Layout

- Turn the gain adjustment potentiometer, R29, 12 turns clockwise to its maximum setting.

- Turn R29, the gain adjustment pot, 5 turns counter-clockwise to put it near the center of the potentiometer.

- While feeding span gas to the analyzer and waiting until the STABIL value is below 1.0 ppb, look at the front panel and scroll to the NORM PMT value. This value is what you are going to adjust to get a slope of 1.000. There are two different equations for calculating your TARGET NORM PMT value. If you are on a range 2000 and below you will want to use the first equation, with a range 2000.1 and above you will use the second equation.

  CONC=Span Gas in PPB

  Ranges 2000.0 and below
  TARGET NORM PMT=(2*CONC)
  Ranges 2000.1 and above
  TARGET NORM PMT=(0.182*CONC)
- Set the HVPS coarse adjustment switch to the lowest setting that will give you more then the calculated TARGET NORM PMT voltage.

- Adjust the HVPS fine adjustment such that the NORM PMT value is as close as possible to the TARGET NORM PMT value. It may be necessary to go back and forth between coarse and fine adjustments if the proper value is at the threshold of the min/max coarse setting.

NOTE

Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. This can cause permanent damage to the PMT.

- Adjust the NORM PMT value with the gain potentiometer to the TARGET NORM PMT value. This is the final very-fine adjustment.

- Perform software span and zero calibrations to normalize the sensor response to its new PMT sensitivity.

- Review the slope and offset values, the slopes should be 1.000±0.300 and the offset values should be -50 to +150 mV.

Pressure Calibration

To calibrate the pressure in the analyzer the first thing you will want to do is disconnect the pump. You can either do this pneumatically or electrically. Also disconnect any tubing connected to the sample inlet port on the back of the analyzer. This will put the analyzer at atmospheric (ambient) pressure.

Next, find what the current atmospheric pressure is. This can be found from a barometer or by contacting your local airport or weather station.

From the front panel of the analyzer press <SETUP><MORE><DIAG> and enter 929 for the password whenever it asks for it. Once in the DIAG menu, press NEXT until you get to Pressure Calibration and hit ENTER. Now enter the current atmospheric pressure and press ENTER.

Exit back out to the main menu and scroll over to sample pressure and rcell pressure. These should be equal to the atmospheric pressure. Reconnect the pump and the pressure should drop about an inch and the rcell pressure should drop below 10"Hg. Reconnect the sample inlet and the pressure should remain the same +- 0.2"Hg. If the pressure changes more than this when you reconnect the sample line, you will have to troubleshoot the system as the analyzer is being pressurized or being put under a vacuum.

Flow Calibration

With the analyzer on and the pump connected and running, connect an external flow meter to the sample inlet port on the back of the analyzer. Record this flow rate. Then disconnect the 1/8" ozone line going into the top of the reaction cell. This is the tubing going into the fitting marked .004. Measure the flow rate going into the fitting, it should be around 80cc/min, and record this reading. Reconnect the 1/8" tubing you previously disconnected to the ozone fitting. Then from the front panel hit <SETUP><MORE><DIAG> enter 929 for the password when it asks you for it.

Once in the DIAG menu press NEXT until you get Flow Calibration and hit <ENTER><SAMP>. Now enter the value you measured with the external flow meter on the sample inlet and hit Enter. Next, do the same thing for the Ozone flow. This will calibrate the flow meter in the analyzer. Exit back out to the main menu and scroll through the TST values till you get Sample Flow and Ozone Flow. They should be reading close to the measured value.

Electric and Optic Test Adjustment

Electric Test

Adjust R19 on PMT Preamp Board

PMT: 2000 MV NO: 1000 PPB

PMT: 2000MV NOx: 1000 PPB

OPTIC TEST

Adjust R28 on PMT Preamp Board

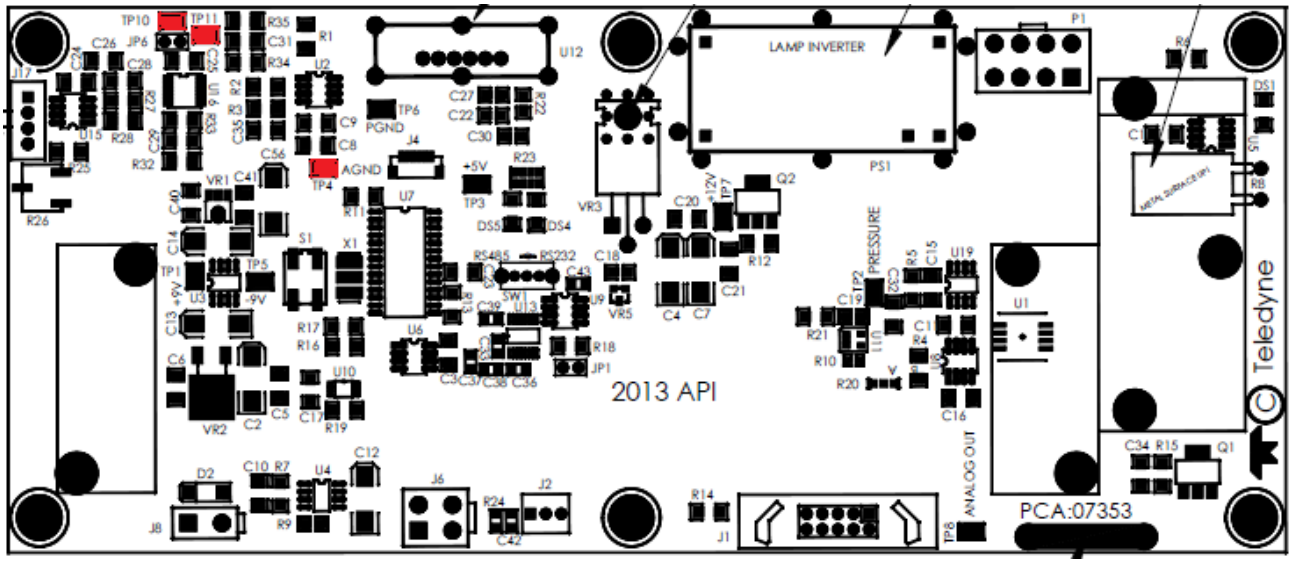
PMT: 2000 MV NO: 1000 PPB

O3 Lamp Adjust

1. Loosen the lamp screws.

2. Connect meter from TP4 to TP10 and rotate lamp to get lamp voltage around 1300mV and tighten lamp down.

3. Connect meter from TP4 to TP11 and adjust pot R26 till you get around 1130mV



MAINTAINANCE

ITEM	ACTION	FREQ	CAL CHECK REQ'D	DATE PERFORMED									
TEST functions	Review and evaluate	Weekly	No										
Particulate filter	Change particle filter	Weekly (if in stack system: As Needed)	No										
Zero/span check	Evaluate offset and slope	Weekly	No										
Zero/span calibration	Zero and span calibration	Every 3 months	**Yes**										
External zero air scrubber option	Exchange chemical	Every 3 months	No										
External dryer option	Replace chemical	When indicator color changes	No										
Ozone cleanser	Change chemical	Annually	**Yes**										
Reaction cell window ("optical filter")	Clean	Annually or as necessary	**Yes**										
DFU filters	Change particle filter	Annually	No										
Pneumatic sub-system	Check for leaks in gas flow paths	Annually or after repairs involving pneumatics	**Yes if a leak is repaired**										
Reaction cell O-rings & sintered filters	Replace	Annually	**Yes**										
PMT Sensor Hardware Calibration	Low-level hardware calibration	On PMT/ preamp changes or if slope is outside of 1.0±0.3	**Yes**										
Pump	Rebuild head	when RCEL pressure exceeds 10 in-Hg-A (at sea level)	**Yes**										
Inline Exhaust Scrubber	Replace	Annually	No										
NO_2 converter	Replace converter	Every 3 years or if conversion efficiency drops below 96%	**Yes**										
Desiccant bags	Replace	Any time PMT housing is opened for maintenance	n/a										

ITEM	ACTION	FREQ	CAL CHECK REQ'D	DATE PERFORMED									
O3 SENSOR MAINTENANCE													
Internal Particulate Filter	Replace	Weekly / As needed											
UV Lamp	Adjust	As needed											
UV Lamp	Replace	When adjustment no longer effective											
Sensor Module Valve	Replace	~ Every 2 years											
*or every 6 mo. when external sample line pre-filters are used.													

PREDICTIVE DIAGNOSTICS

Predictive diagnostic functions including failure warnings and alarms built into the analyzer's firmware allow the user to determine when repairs are necessary.

The Test Functions can also be used to predict failures by looking at how their values change over time. Initially it may be useful to compare the state of these Test Functions to the values recorded on the printed record of the *Final Test and Validation Data Sheet*.

The following table can be used as a basis for taking action as these values change with time (recommend weekly check). The internal data acquisition system (DAS) is a convenient way to record and track these changes. Use APICOM to download and review this data from a remote location.

Predictive Uses for Test Functions

FUNCTION	EXPECTED	ACTUAL	INTERPRETATION & ACTION
RCEL (pressure)	Constant to within ± 0.5 in-Hg-A	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Pump performance is degrading. Rebuild pump when pressure is above 10 in-Hg-A.
SAMP (pressure)	Constant within atmospheric changes	Fluctuating	Developing leak in pneumatic system. Check for leaks.
		Slowly increasing	Flow path is clogging up. Replace orifice filters.
		Slowly decreasing	Developing leak in pneumatic system to vacuum (developing valve failure). Check for leaks.
OZONE FL[1]	Constant to within ± 15	Slowly decreasing	Flow path is clogging up. Replace orifice filters.
AZERO	Constant within ±20 of check-out value	Significantly increasing	Developing AZERO valve failure. Replace valve.
			PMT cooler failure. Check cooler, circuit, and power supplies.
			Developing light leak.
			O_3 air filter cartridge is exhausted. Change chemical.
NO_2 (Concentration)	Constant for constant concentrations	Slowly decreasing signal for same concentration	Converter efficiency may be degrading. Replace converter components.
NO (Concentration)	Constant for constant concentration	Decreasing over time	Drift of instrument response; clean RCEL window. Check for flow leaks or irregularities.

MAINTENANCE PROCEDURES

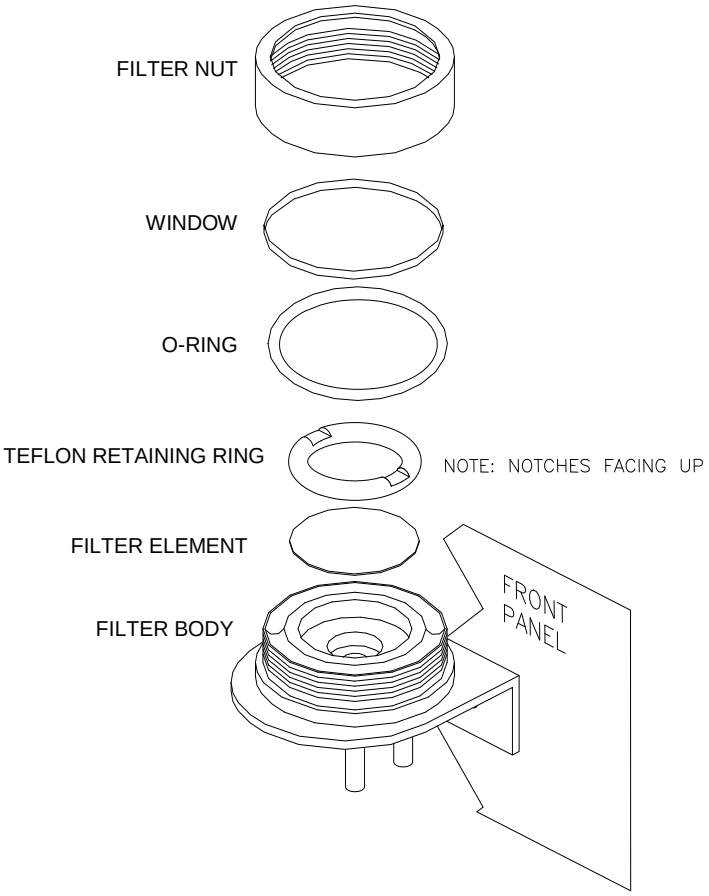
The following procedures are to be performed periodically as part of the standard maintenance of the T204.

REPLACING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or contamination. We recommend that when you change the filter; handle it and the wetted surfaces of the filter housing as little as possible. Do not touch any part of the housing, filter element, retaining ring, glass cover or the o-ring with your bare hands. Teledyne API recommends using gloves or PTFE coated tweezers or similar handling to avoid contamination of the sample filter assembly.

To change the filter

1. Turn OFF the analyzer to prevent drawing debris into the instrument.
2. Open the T204's hinged front panel and unscrew the filter nut on the filter assembly.



Replacing the Particulate Filter

3. Carefully remove the filter nut, PTFE o-ring, glass filter cover and filter element.
4. Replace the filter element, being careful that it is fully seated and centered in the bottom of the holder.

5. Reinstall the Teflon retaining ring with the notches up, the o-ring, and the window; then screw on the filter nut and hand tighten. Inspect the seal between the edge of filter and the Teflon retaining ring to assure a proper seal.
6. Restart the Analyzer.

CHANGING THE O_3 GENERATOR DRYER PARTICULATE FILTER

The air for the O_3 generator passes through a sample gas dryer, which is equipped with a small particulate filter at its inlet. This filter prevents dust from entering the sample gas dryer and degrading the dryer's performance over time. Change the filter according to the service interval in Table:

7. Before starting the procedure, check and write down the average **RCEL** pressure and the **OZONE FLOW** values.
8. Turn off the analyzer, unplug the power cord and remove the cover.
9. Unscrew the nut around the port of the filter using two 5/8" wrenches.

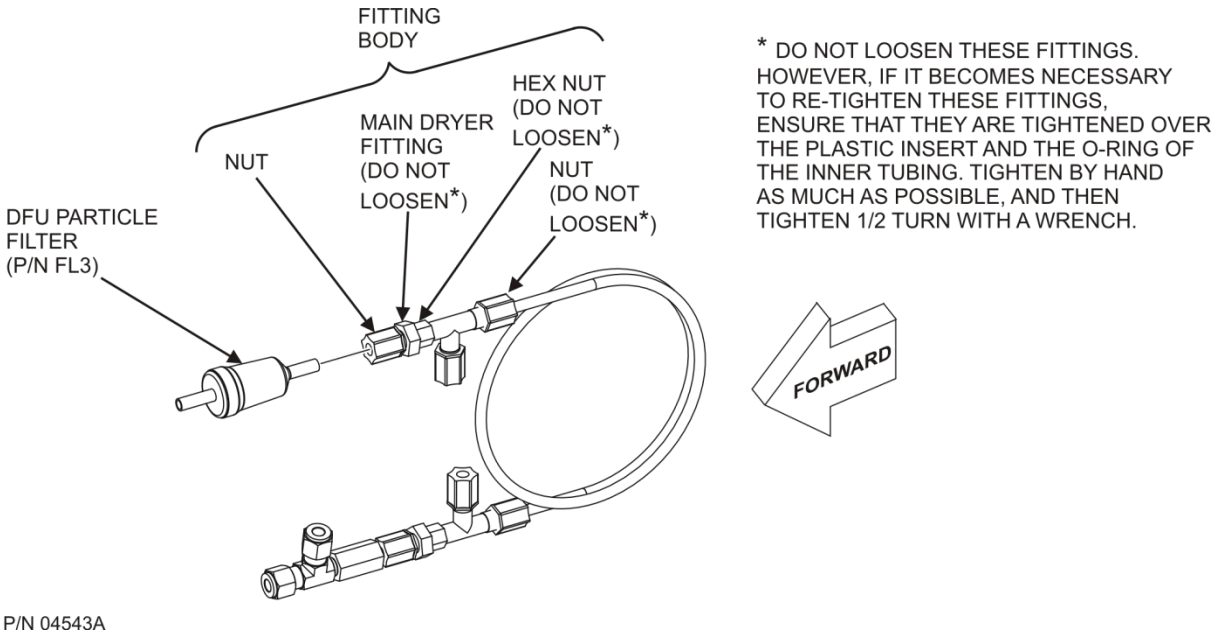
ATTENTION **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

Ensure to use proper wrenches.

Hold the main dryer fitting with a 5/8" wrench to ensure that it does not turn against the sample gas dryer.

Performing this procedure improperly or with incorrect tools creates a risk of causing a significant leak.

10. Take off the old filter element and replace it with a suitable equivalent (Teledyne API P/N FL-3).



Particle Filter on O_3 Generator Supply Air Dryer

5. Holding the main dryer fitting steady with a 5/8” wrench and tighten the nut with your hands.

   If necessary use a second wrench but do not over-tighten the nut.

6. Replace the cover, plug in the power cord and restart the analyzer.
7. Check the O3 flow rate; it should be around 80 cm^3/min ± 15.
8. Check the RCEL pressure.

   It should be the same value as recorded in Step 7 of this procedure.

9. Refer to Section **CHECKING FOR LIGHT LEAKS** to leak check after installing the new DFU particle filter.

CHANGING THE OZONE GENERATOR CLEANSER CHEMICAL

The ozone (O_3) cleanser, located next to the O_3 generator (see below), cleans the O_3 stream from solid and liquid contaminants that are created inside the O_3 generator. The content of the ozone cleanser needs periodical exchange according Table. A rebuild kit is available from the factory (see Appendix B of this manual lists the part numbers).

To change the ozone cleanser chemical, follow these steps:

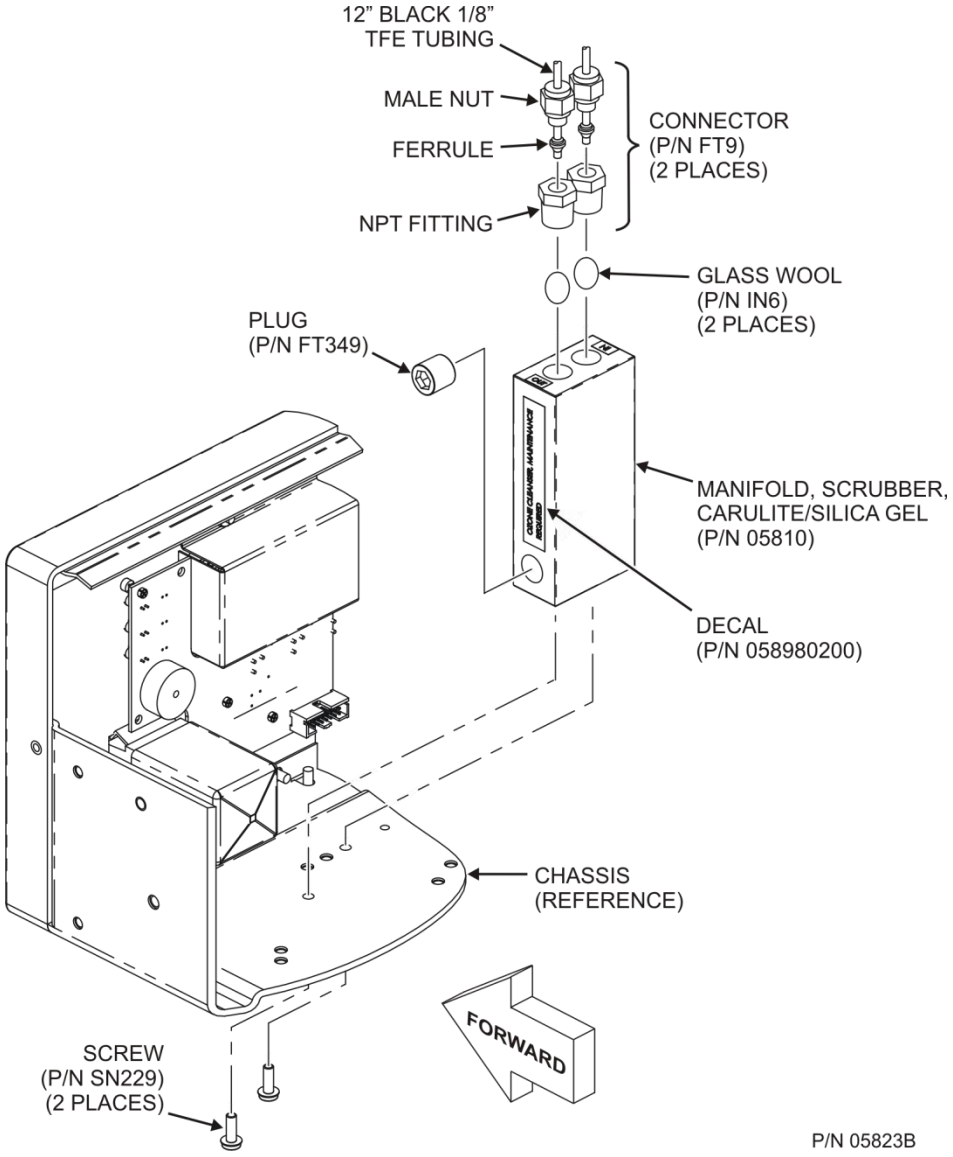
1. Turn of power to the analyzer and pump. Remove the analyzer cover and locate the O_3 filter in the front of the analyzer next to the O_3 generator.
2. Use a 7/16” wrench to remove both pieces of 1/8” male nut with tubing from the NPT fittings.
3. Remove the integrated screws with a Phillips screw driver and remove the scrubber manifold from the chassis.
4. Using a 9/16” wrench, remove both fittings from the cartridge.
5. Discard the glass wool.
6. Pour the contents of the scrubber manifold onto a sheet of white paper. If necessary, remove the plug to ensure that all the contents are poured out.

   Notice any discoloration of the contents, which is usually white and slightly transparent.

   The amount of discolored chemical (usually with yellow tint) may give you an indication of the lifetime of the chemical in your application.

The maintenance cycle of this item is dependent on ambient moisture, sub-micron particle load and other factors and may differ from that shown in Table.

7. Discard the used silica gel desiccant without touching it. It may contain nitric acid, which is a corrosive and highly irritating substance.



Ozone Generator Cleanser Assembly

CAUTION – GENERAL SAFETY HAZARD

Immediately wash your hands after contact with the silica gel disiccant.

1. Using a small powder funnel, fill the cartridge with about 10 g new silica gel desiccant (Teledyne API P/N CH43) so that it is level on both legs of the cartridge.

   Slight vibration is required to settle the chemical into the cartridge and achieve tightest packing, which increases performance and lifetime of the filter.

   Ensure that the level of the chemical does not protrude farther than the first two threads of the NPT fitting.

IMPORTANT

IMPACT ON READINGS OR DATA

Use only genuine, pre-conditioned Teledyne API's refill kits for this procedure. Teledyne API's refill kits have been properly conditioned to prevent a significant increase of the T204's Auto Zero value which can cause large negative offsets, which may take 2-3 weeks to disappear.

Do not leave this material uncovered for more than a few seconds, as it will absorb contaminants from ambient air. Always store unused, well-covered refill material in a cool dry place.

2. Seal the silica gel desiccant with 1 cm^3 of glass wool on each well.

   Ensure that the plug is large enough and compressed into the cartridge so that the chemical is securely held in place.

3. Add new Teflon tape (P/N HN000036) to the NPT fittings.
4. Screw the NPT fittings back into the scrubber manifold.
5. Screw the cartridge back onto the chassis; orientation is not important.
6. Evaluate the ferrules on the tubing.

   If the ferrules are too old, we recommend replacing them with new ferrules.

7. Reconnect the tubing using 7/16" and 9/16" wrenches.

   Do not over-tighten the fittings.

8. If the service interval for this item has been exceeded, it may also be necessary to clean the reaction cell as described in Section 0.
9. Leak check the system using the pressurized approach described in Section 0.

   If necessary, tighten the fittings some more but do not over-tighten.

10. Restart the analyzer and pump and continue operation.
11. Recalibrate the analyzer after one hour .

    If Auto Zero is high or is changing/not constant, you may have to wait a day until the silica gel is conditioned before recalibrating the instrument.

MAINTAINING THE EXTERNAL SAMPLE PUMP (PUMP PACK)

REBUILDING THE PUMP

The sample pump head periodically wears out and must be replaced when the **RCEL** pressure exceeds 10 in-Hg-A (at sea level, adjust this value accordingly for elevated locations).

A pump rebuild kit is available from the factory. Refer to the label on the pump for the part number. Instructions and diagrams are included in the kit.

A flow and leak check after rebuilding the sample pump is recommended.

A span check and re-calibration after this procedure is necessary as the response of the analyzer changes with the **RCEL** pressure.

REPLACING THE SCRUBBER

CAUTION!

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

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

CHANGING THE PUMP DFU FILTER

The exhaust air from the analyzer passes a small particle filter (Dry Filter Unit (*DFU* - filter*)*, P/N FL3) before entering the pump. It should be replaced when:

It becomes visibly dirty or;

The pressure differential between the test functions **SAMP** and **RCEL** increases significantly.

PROCEDURE FOR REPLACING FILTERS ON EXTERNAL PUMPS

1. Power down the analyzer and pump.
2. For internally mounted filters, skip the next two steps.
3. Remove the analyzer exhaust tube from the dust filter.
4. Remove the particle filter from the pump by pushing the white plastic ring into the fitting and pulling the filter out of the fitting.

   If necessary, use needle-nose pliers to pry the filter out of the fittings.

5. Push a new filter into the pump fitting and ensure that the arrow on the filter points towards the pump.
6. Push the exhaust tubing onto the filter. Skip the next two steps.
7. For internally mounted filters at the inside rear panel, remove the chassis and locate the filter between the vacuum manifold and the exhaust port fitting.
8. Disconnect the clear tubing from the filter body and change the filter with the arrow pointing against the gas flow. To remove the hose clamps, slide the two clamp ends in opposite directions with a needle-nose pliers until the clamp comes apart. Reconnect the tubing by using the same or new clamps and pushing tightening them until a good seal is achieved.
9. Restart the pump and clear any error warnings from the front panel display.
10. After about 5 minutes, check the RCEL pressure reading and ensure that it is similar to its value before changing the filter but less than 10 in-Hg-A.

    Ensure that the three screws are tightened evenly.

11. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.
12. Carry out a span check to see if the new permeation device works.
13. The permeation rate may need several days to stabilize.

ATTENTION **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 NO2, even at room temperature and will contaminate the entire instrument.

CHANGING THE NO_2 CONVERTER

The NO_2 converter is located in the center of the instrument;

The converter is designed for replacement of the cartridge only; the heater with built-in thermocouple is to be reused.

CAUTION
HOT SURFACE HAZARD

The converter operates at 315º C. Severe burns can result if the assembly is not allowed to cool.

Do not handle the assembly until it is at room temperature. This may take several hours

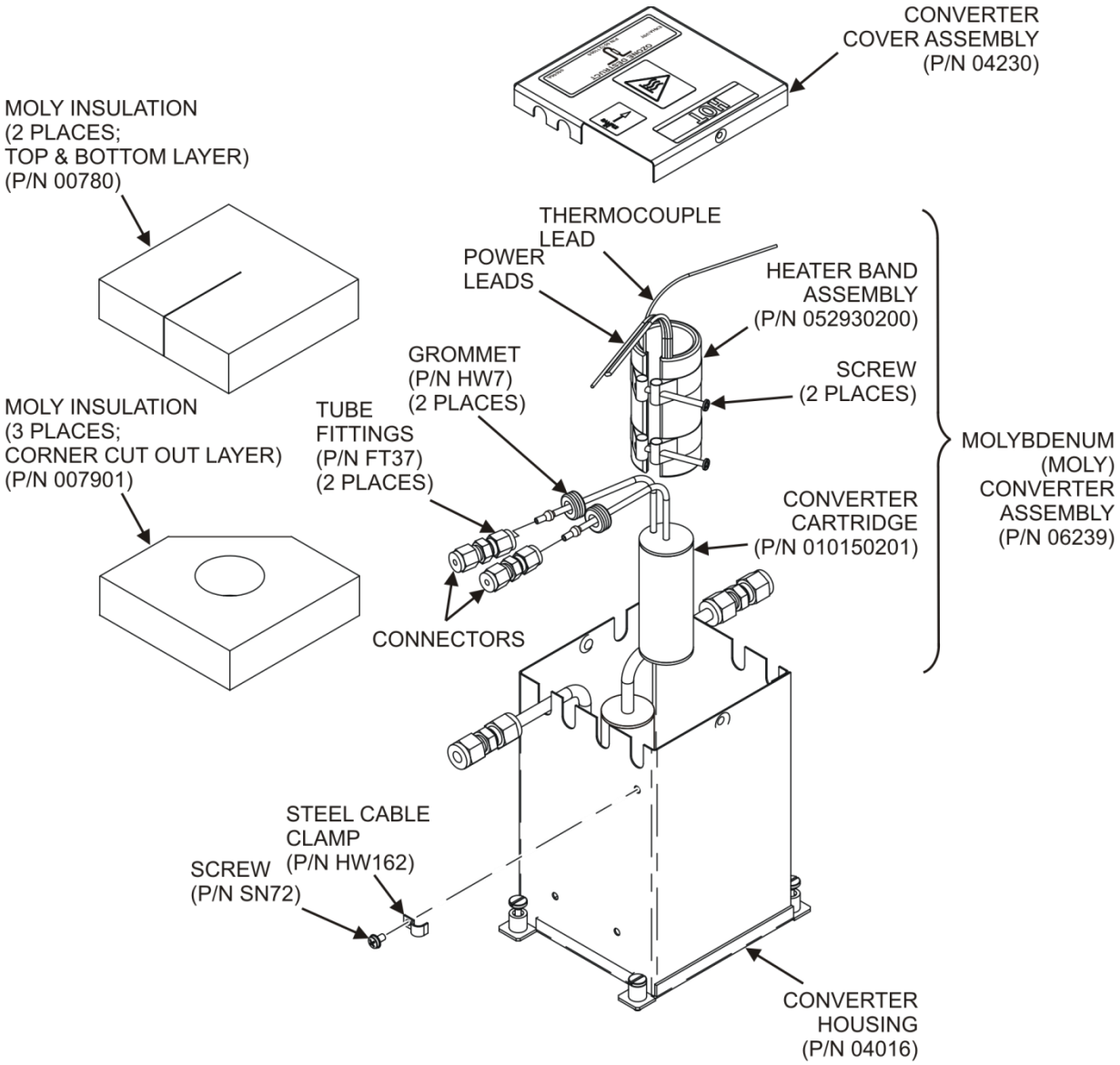
CAUTION!

Wear gloves prior to changing the NO_2 Converter to ensure that the fiberglass insulation does not come into contact with your skin.

1. Turn off the analyzer power.
2. Remove the instrument cover and allow the converter to cool.
3. Remove the converter assembly cover as well as the Moly insulation (top layer and corner cut out layers) until the Moly converter assembly can be seen.
4. Remove the tube fittings from the Moly converter assembly.
5. Disconnect the power and the thermocouple from the Moly converter assembly.
6. Unscrew the steel cable clamp (for the power leads) from the converter housing with a Phillips-head screw driver.
7. Remove the Moly converter assembly (converter cartridge and band heater) from the converter housing.

   Make a note of the orientation of the tubes relative to the heater cartridge.

8. Unscrew the band heater and loosen it.
9. Remove the old converter cartridge.



P/N 0187202G

NO_2 Converter Assembly

1. Wrap the band heater around the new replacement converter cartridge and tighten the screws using a high-temperature anti-seize agent (Teledyne API P/N CH42) such as copper paste.

   Ensure to use proper alignment of the heater with respect to the converter tubes.

2. Replace the Moly converter assembly by routing the cables through the holes in the converter housing and reconnecting them properly.
3. Reconnect the steel cable clamp around the power leads for safe operation.
4. Reattach the tube fittings to the converter and replace the Moly insulation (top layer and corner cut out layers).

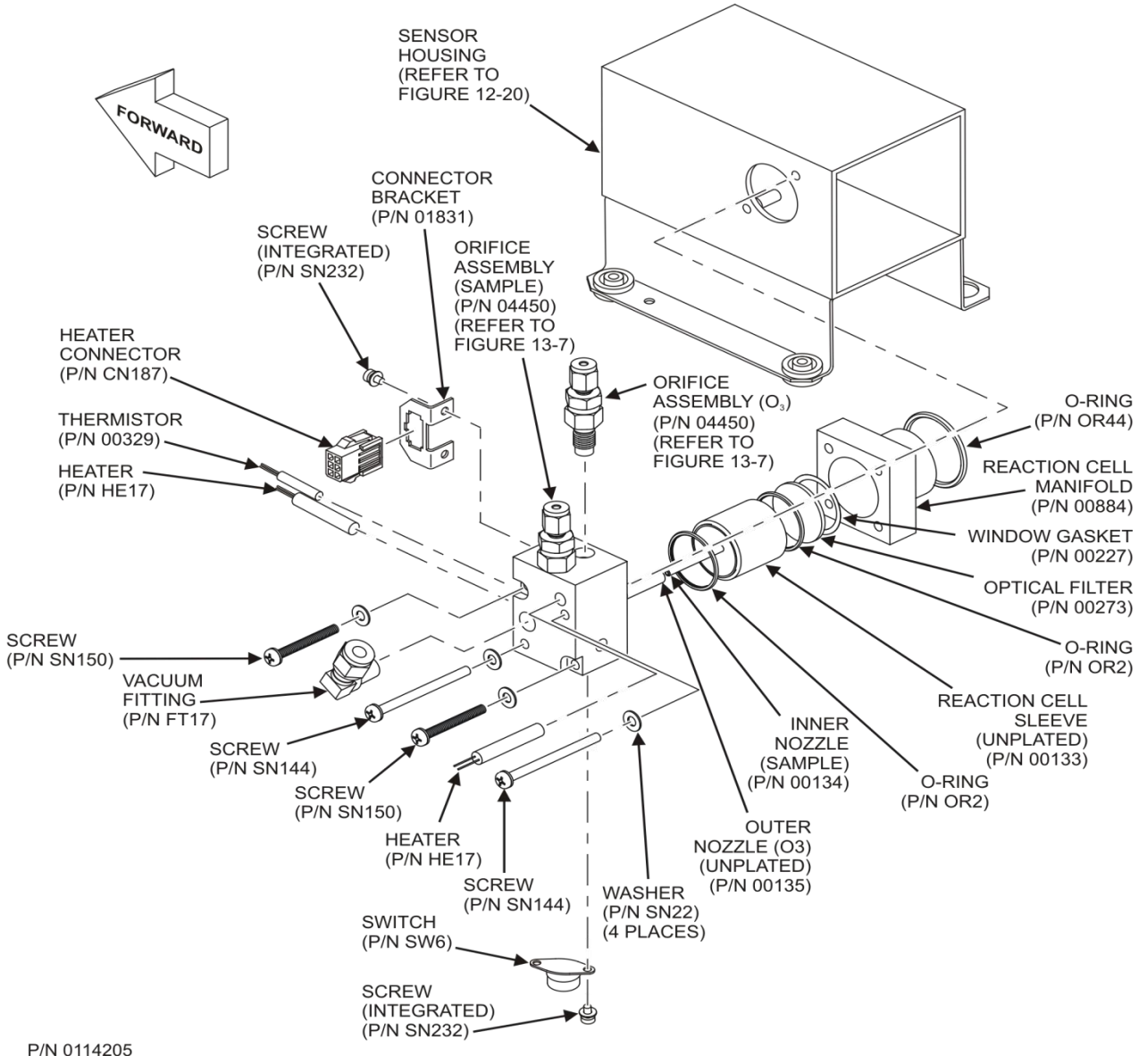
5. Reinstall the converter assembly cover.
6. Reinstall the instrument cover and power up the analyzer.
7. Allow the converter to burn-in for 24 hours, and then recalibrate the instrument.

CLEANING THE REACTION CELL

A dirty reaction cell will cause excessive noise, drifting zero or span values, low response or a combination of all.

To clean the reaction cell, it is necessary to remove it from the sensor housing.

1. Turn off the instrument power and vacuum pump.
2. Disconnect the black 1/4" exhaust tube and the 1/8" sample and ozone air tubes from the reaction cell. Disconnect the heater/thermistor cable.
3. Remove two screws (Teledyne API P/N SN144) and two washers holding the reaction cell to the PMT housing and lift the cell and manifold out.



Reaction Cell Assembly

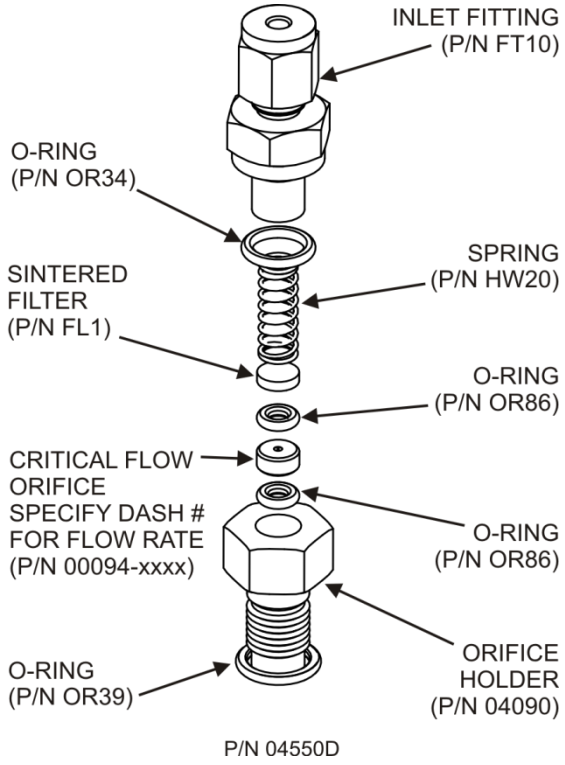
4. Remove two screws (Teledyne API P/N SN150) and two washers.
5. The reaction cell will separate into two halves, the stainless steel manifold assembly and the black plastic reaction cell with window gasket, stainless steel reaction cell sleeve, optical filter and O-rings.
6. The reaction cell (both plastic part and stainless steel sleeve) and optical filter should be cleaned with Distilled Water (DI - Water) and a clean tissue, and dried thereafter.
7. Usually it is not necessary to clean the sample and ozone flow orifices since they are protected by sintered filters.

   If tests show that cleaning is necessary.

8. Do not remove the sample and ozone nozzles. They are Teflon threaded and require a special tool for reassembly. If necessary, the manifold with nozzles attached can be cleaned in an ultrasonic bath.
9. Reassemble in proper order and re-attach the reaction cell to the sensor housing. Reconnect pneumatics and heater connections, then re-attach the pneumatic sensor assembly and the cleaning procedure is complete.
10. After cleaning the reaction cell, it is also recommended to exchange the ozone supply air filter chemical .
11. After cleaning, the analyzer span response may drop 10 - 15% in the first 10 days as the reaction cell window conditions. This is normal and does not require another cleaning.

REPLACING CRITICAL FLOW ORIFICES

There are several critical flow orifices installed in the T204. Despite the fact that these flow restrictors are protected by sintered stainless steel filters, they can, on occasion, clog up, particularly if the instrument is operated without sample filter or in an environment with very fine, sub-micron particle-size dust.



Critical Flow Orifice Assembly

To clean or replace a critical flow orifice:

1. Turn off power to the instrument and vacuum pump.
2. Remove the analyzer cover and locate the reaction cell
3. Unscrew the 1/8" sample and ozone air tubes from the reaction cell.
4. For orifices on the reaction cell above. Unscrew the orifice holder with a 9/16" wrench.
   This part holds all components of the critical flow assembly as shown above
5. For orifices in the vacuum manifold: the assembly is similar to the one above except:
   Without the orifice holder, P/N 04090, and bottom O-ring, P/N OR34 and; With an NPT fitting in place of the FT 10 fitting.
6. After taking off the connecting tube, unscrew the NPT fitting.
7. Take out the components of the assembly:
   - spring
   - sintered filter
   - two O-rings
   - the orifice

Note **For the vacuum manifold only, you may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.**

8. Discard the two O-rings and the sintered filter and install new ones.
9. Reassemble the parts as shown above
10. Reinstall the critical flow orifice assembly into the reaction cell manifold or the vacuum manifold.
11. Reconnect all tubing, power up the analyzer and pump. After a warm-up period of 30 minutes, carry out a leak test .

CHECKING FOR LIGHT LEAKS

When re-assembled or operated improperly, the T204 can develop small gaps around the PMT, which let stray light from the analyzer surrounding into the PMT housing. To find such light leaks, follow the procedures below.

CAUTION – QUALIFIED PERSONNEL ONLY

This procedure is carried out with the analyzer running and its cover removed.

1. Scroll the front panel display to show then test function to **PMT**.
2. Supply zero gas to the analyzer.
3. With the instrument still running, carefully remove the analyzer cover.

WARNING – ELECTRICAL SHOCK HAZARD

Do NOT touch any of the inside wiring with the metal cover or with your body.

Do NOT drop screws or tools into a running analyzer.

4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the reaction cell as well as around the PMT housing.

   The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise floor.

5. If there is a PMT response to the external light, symmetrically tighten the reaction cell mounting screws or replace the 1/4” vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent).

Note **Often, light leaks are also caused by O-rings being left out of the assembly.**

6. Replace the five desiccant bags in the PMT housing if the PMT housing end plate was removed during this procedure.
7. Carefully replace the analyzer cover. If tubing was changed, carry out a pneumatic leak check.

CHECKING FOR PNEUMATIC LEAKS

CAUTION - TECHNICAL INFORMATION

Do not exceed 15 psi when pressurizing the system during either Simple or Detailed checks.

SIMPLE VACUUM LEAK AND PUMP CHECK

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

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

DETAILED PRESSURE LEAK CHECK

If a leak cannot be located by the above procedure. Alternatively, a tank of pressurized gas, with the two-stage regulator adjusted to ≤ 15 psi, a shutoff valve and a 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 reapply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

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. Disconnect the pump tubing on the outside rear panel and cap the pump port.
    - Cap the DFU particle filter on the sample gas dryer.
4. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.
    - Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.

- Once the fittings have been wetted with soap solution, do not reapply vacuum as it will draw soap solution into the instrument and contaminate it.
- Do not exceed 15 psi pressure.

5. If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked.

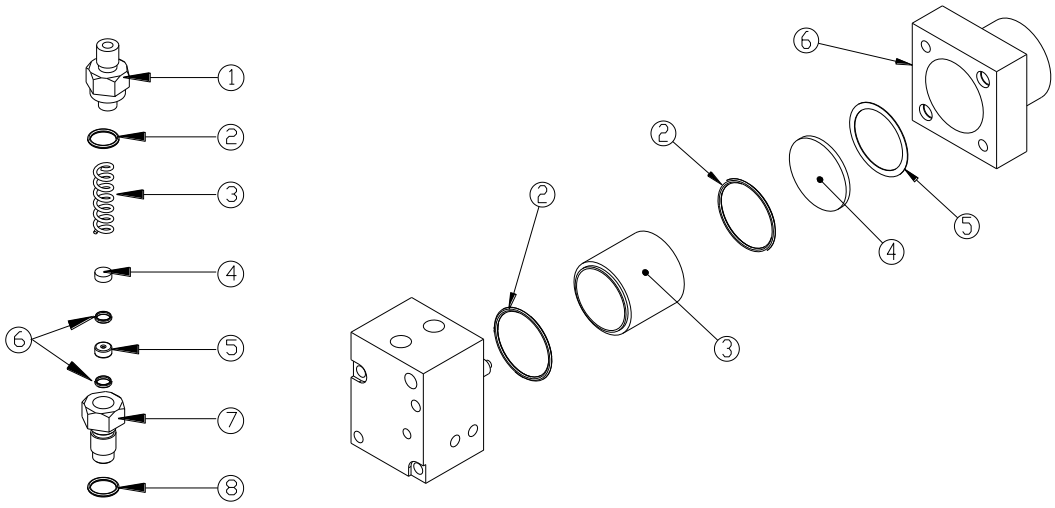
6. Connect the leak checker to the normally closed ports and check with soap bubble solution.

7. 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.

8. Clean surfaces from soap solution, reconnect the sample and pump lines and replace the instrument cover.

9. Restart the analyzer.

The Reaction Chamber

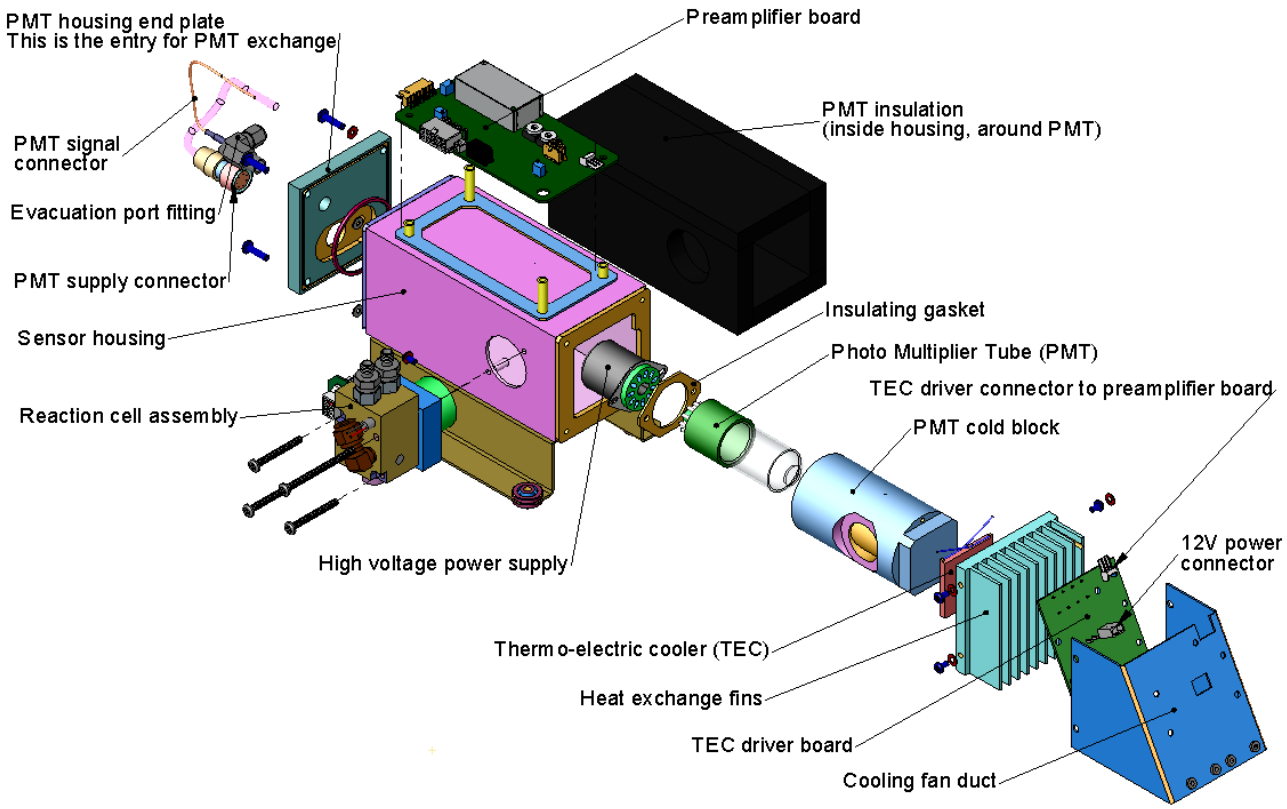


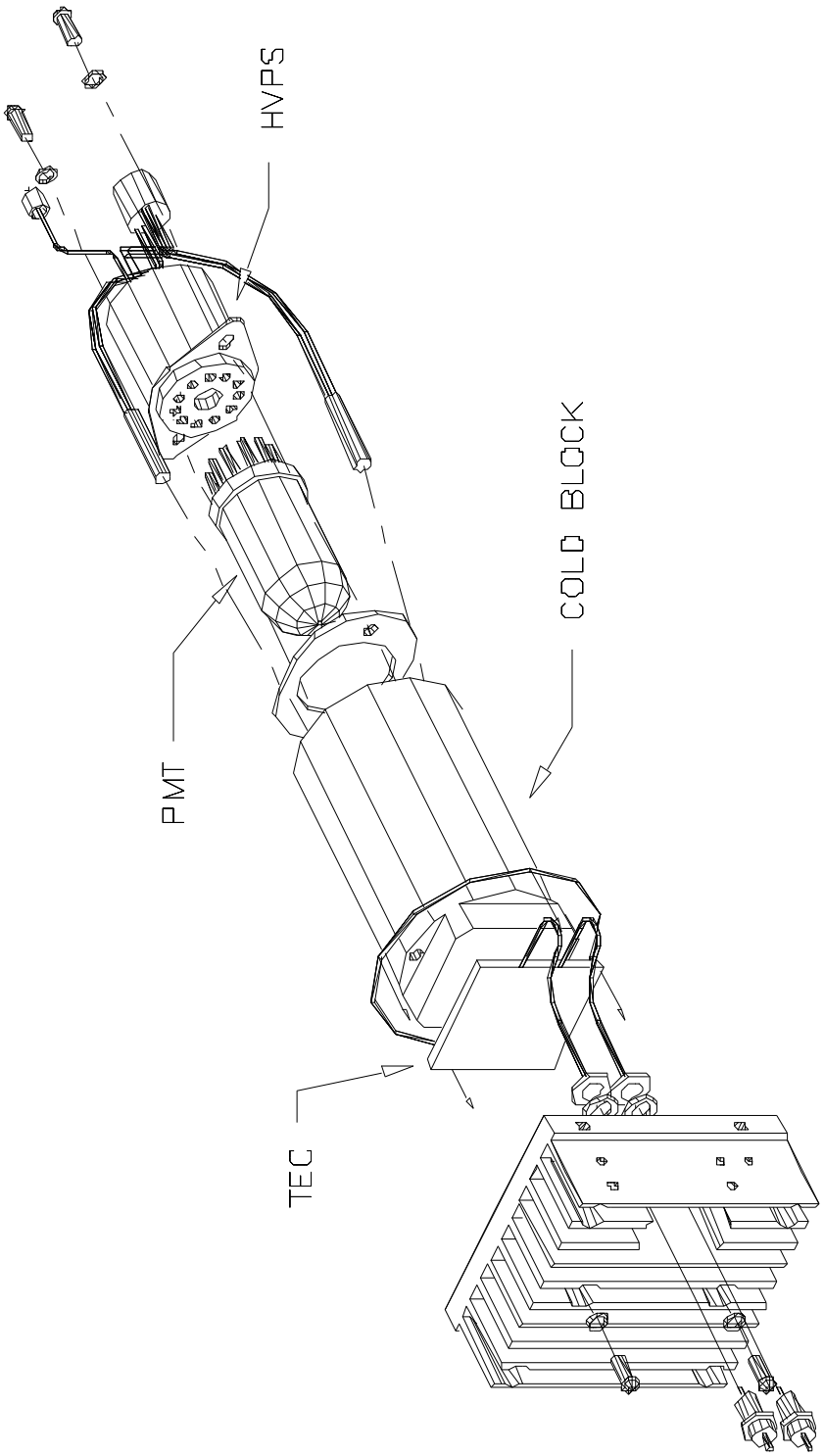
Orifice Holder Assy

1. FT0000010
2. OR0000034
3. HW0000020
4. FL0000001
5. 000940400 (Ozone)
5. 000940600 (Sample)
6. OR0000086
7. 040900000
8. OR0000039

Reaction Cell Assy

2. OR0000002
3. 001330000
4. 002730000
5. 002270000
6. 008840000





PMT COOLER ASSEMBLY

T204 Warning Messages

Possible Warning Messages at Start-Up

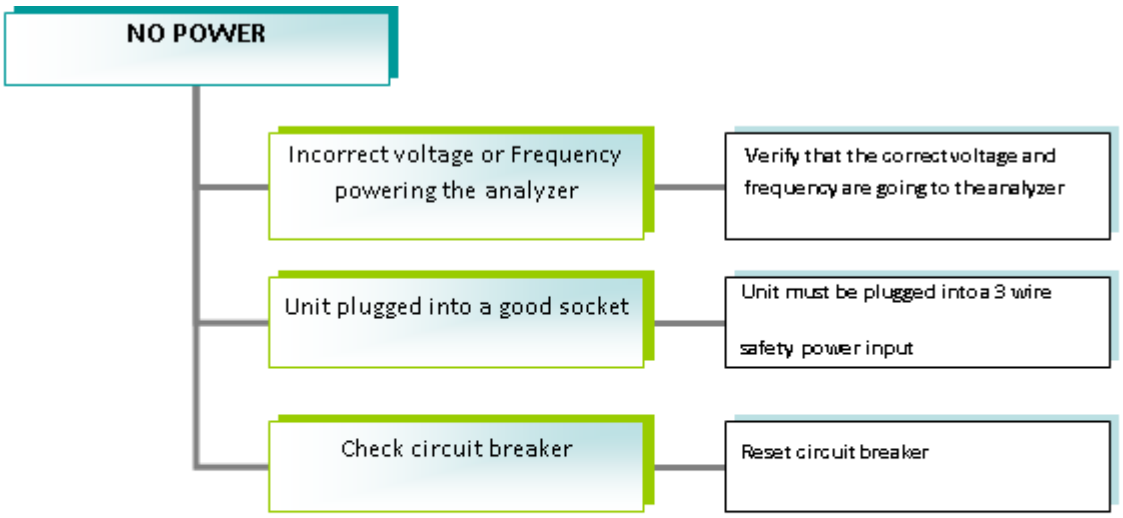
MESSAGE	MEANING
SYSTEM RESET[1]	The computer has rebooted.
ANALOG CAL WARNING	The A/D or at least one D/A channel have not been calibrated.
BOX TEMP WARNING	The temperature inside the T204 chassis is outside the specified limits.
CANNOT DYN SPAN[2]	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
CANNOT DYN ZERO[3]	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
DATA INITIALIZED	DAS data storage was erased before the last power up occurred.
OZONE FLOW WARNING	Ozone generator gas flow is too high or too low for accurate NO_x, NO and NO_2 readings.
OZONE GEN OFF [4]	Ozone generator is off. This is the only warning message that automatically clears itself. It clears itself when the ozone generator is turned on. Upon power up the Ozone generator will remain off for 30 minutes. This allows the perma-pure dryer to reach its working dew point.
RCELL PRESS WARN	Reaction cell pressure is too high or too low for accurate NO_x, NO and NO_2 readings.
RCELL TEMP WARNING	Reaction cell temperature is too high or too low for accurate NO_x, NO and NO_2 readings.
CONV TEMP WARNING	NO_2 to NO Converter temperature too high or too low to efficiently convert NO_2 to NO.
PMT TEMP WARNING	PMT temperature outside of warning limits.
AZERO WARN *[XXXX]* MV	AutoZero reading too high. The value shown in message indicates auto-zero reading at time warning was displayed.
HVPS WARNING	High voltage power supply output is too high or too low for proper operation of the PMT.
REAR BOARD NOT DET	CPU unable to communicate with motherboard..
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.

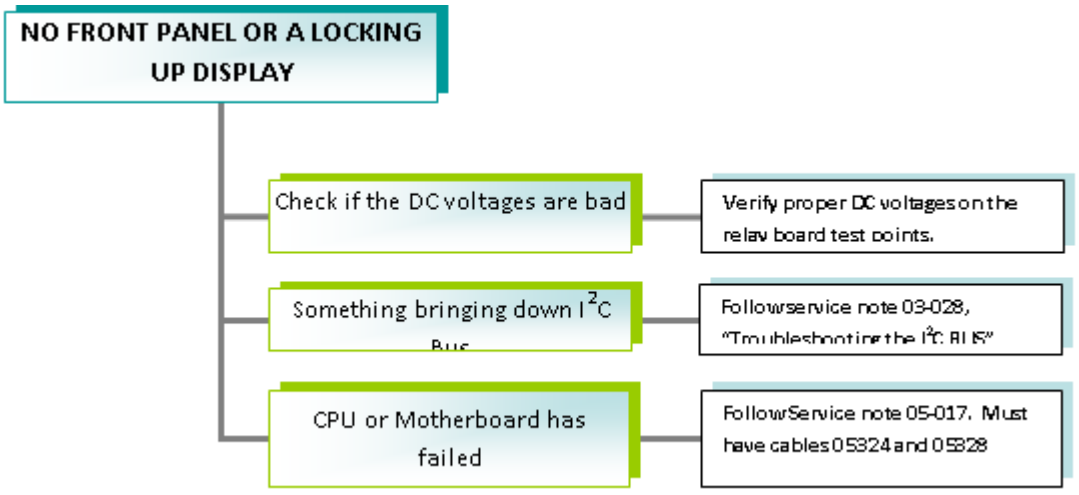
[1] Clears 45 minutes after power up.
[2] Clears the next time successful zero calibration is performed.
[3] Clears the next time successful span calibration is performed.
[4] Clears 30 minutes after power up.

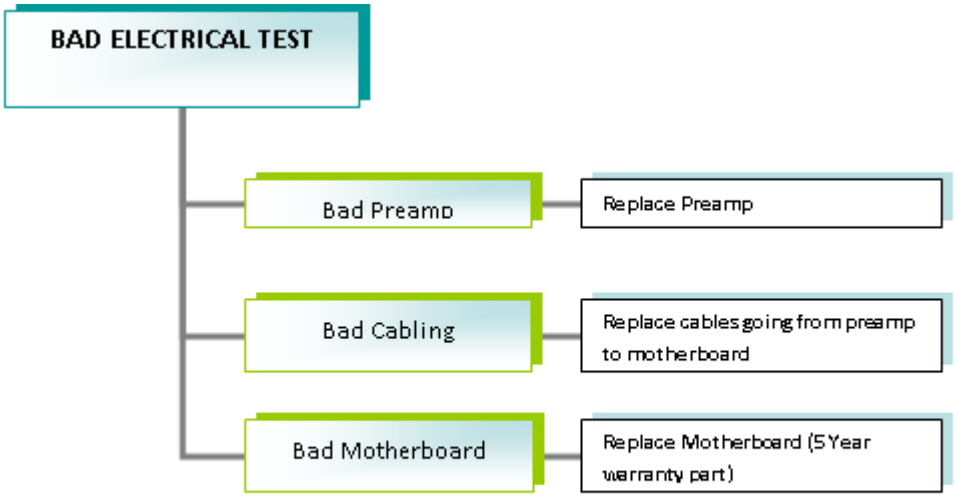
Warning Messages Defined

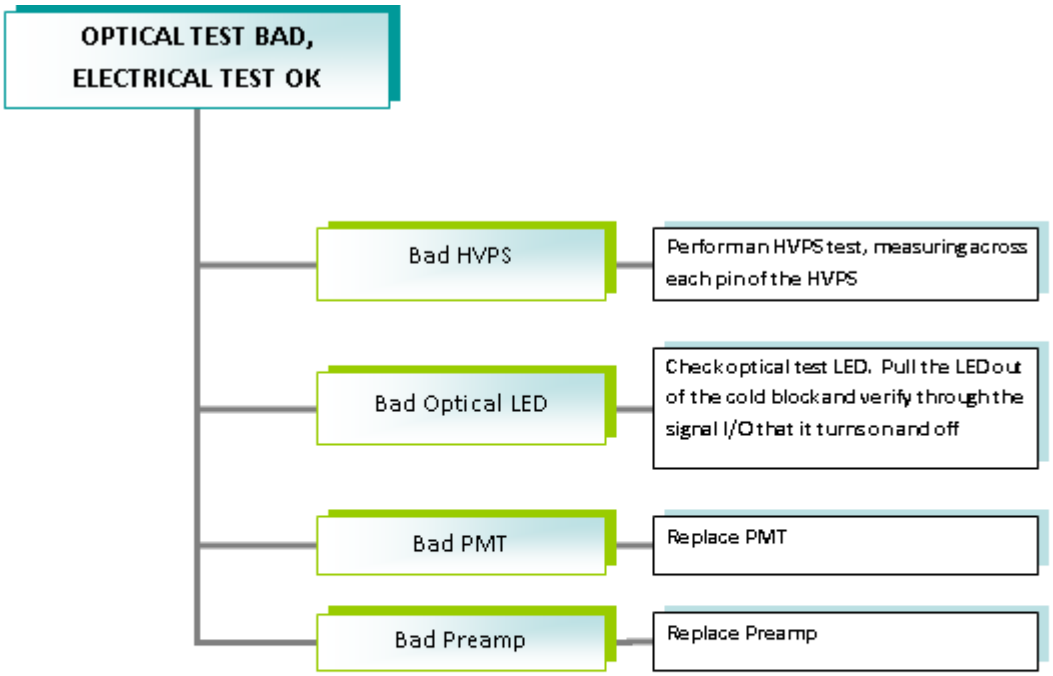
MESSAGE	MEANING
ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.
AZERO WARN	Auto-zero reading above limit. Value shown in message indicates auto-zero reading at time warning was displayed.
BOX TEMP WARNING	The temperature inside the T204 chassis is outside the specified limits.
CANNOT DYN SPAN	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
CANNOT DYN ZERO	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
CONV TEMP WARNING	NO_2 → NO converter temperature outside of warning limit.
DATA INITIALIZED	DAS data storage was erased before the last power up occurred.
HVPS WARNING	High voltage power supply output outside of warning limits.
O3 ALARM1 WARNING	O_3 concentration alarm limit #1 exceeded.
O3 ALARM2 WARNING	O_3 concentration alarm limit #2 exceeded.
O3 CELL TEMP WARN	O_3 sensor sample temperature outside of warning limit.
O3 CELL PHOTOREF WARN	O_3 sensor photometer reference signal warning.
O3 CELL LAMP WARN	O_3 cell lamp temperature warning.
O3 CELL PRESS WARN	O_3 cell pressure warning.
OZONE FLOW WARNING	Ozone Generator flow outside of warning limits.
OZONE GEN OFF	Ozone generator is off. This warning message clears itself when the ozone generator is turned on.
PMT TEMP WARNING	PMT temperature outside of warning limits.
RCELL PRESS WARN	Reaction cell pressure outside of warning limits.
RCELL TEMP WARNING	Reaction cell temperature outside of warning limits.
REAR BOARD NOT DET	Motherboard was not detected during power up.
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SYSTEM RESET	The computer has rebooted.

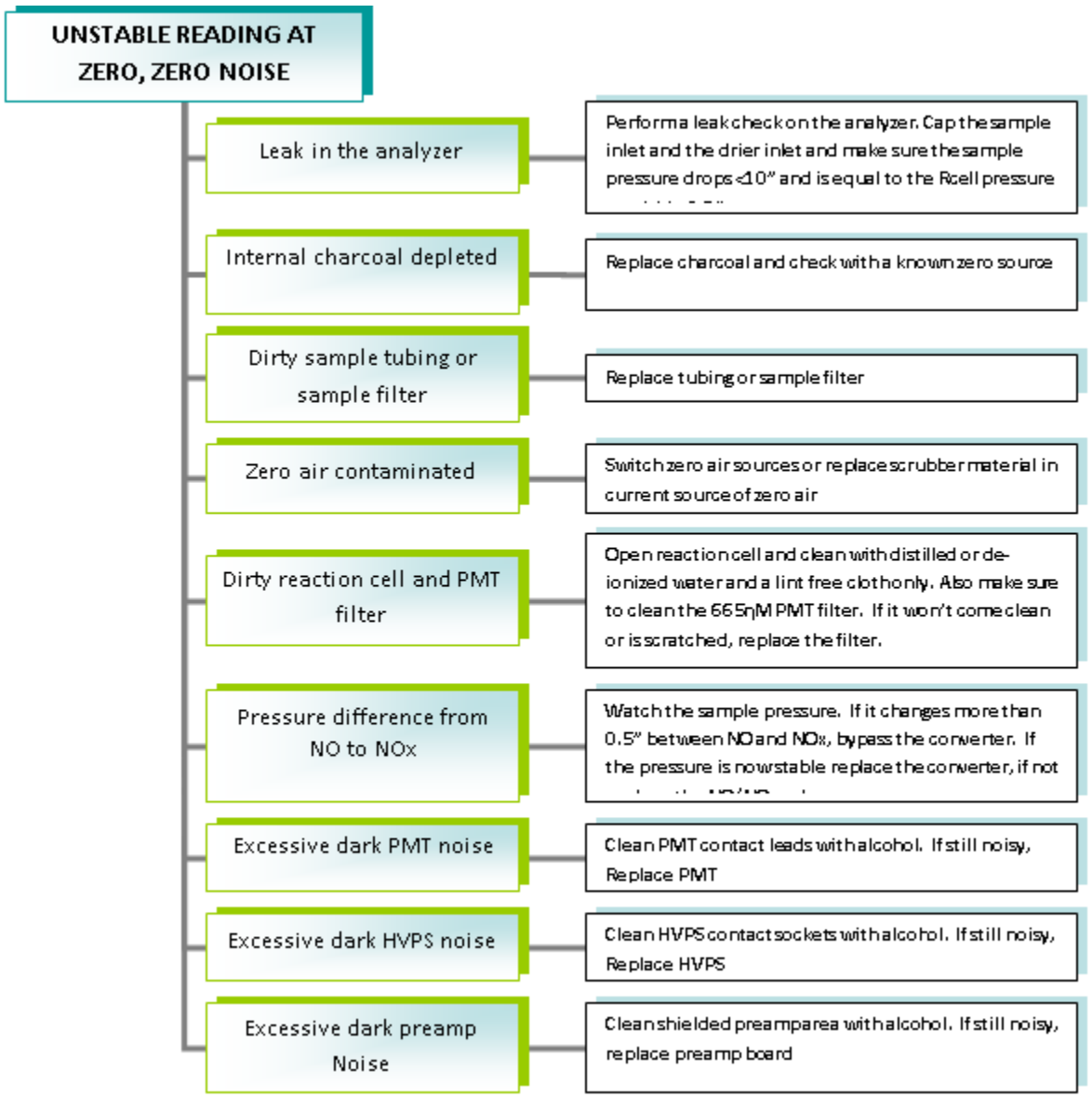
T204 TROUBLESHOOTING TREE

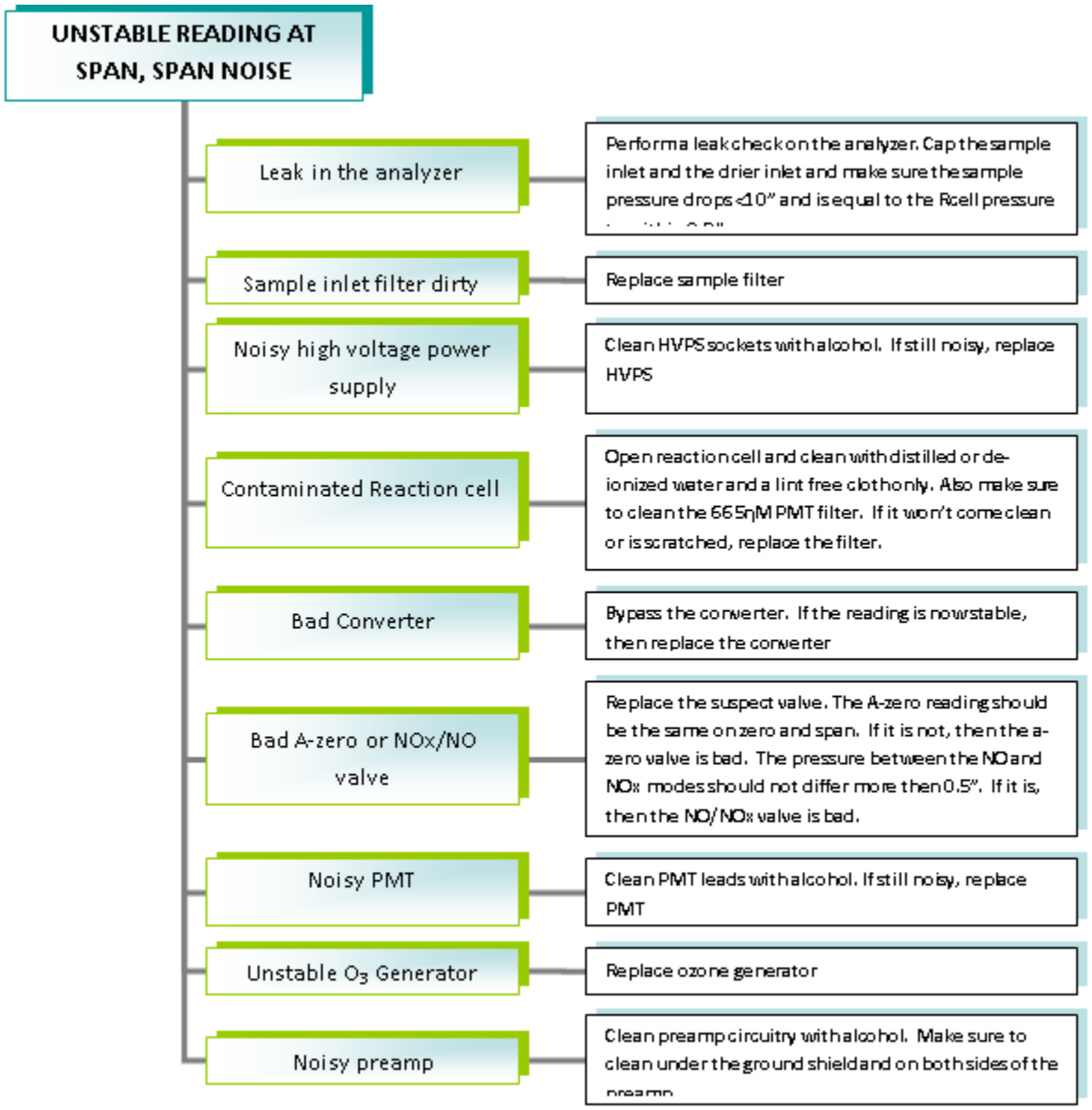


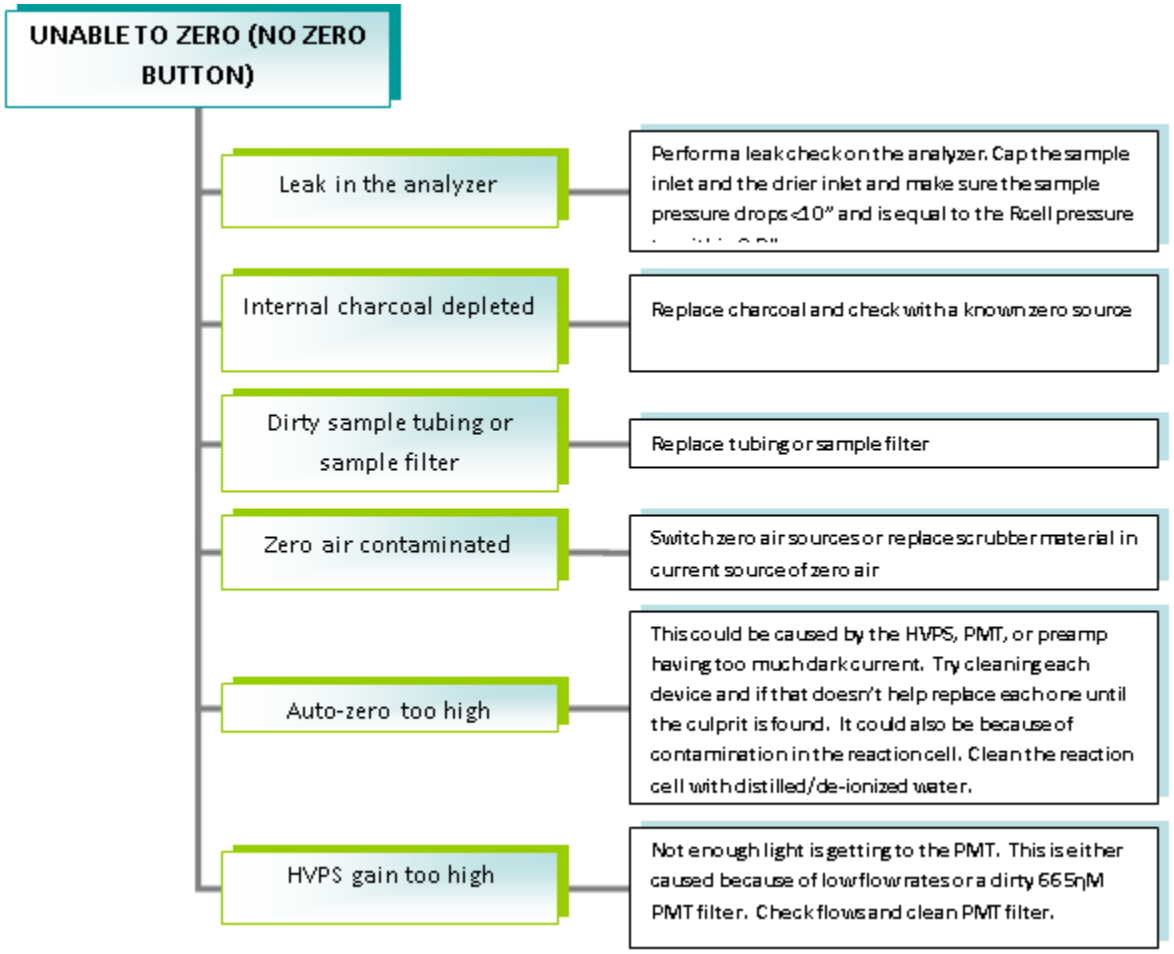


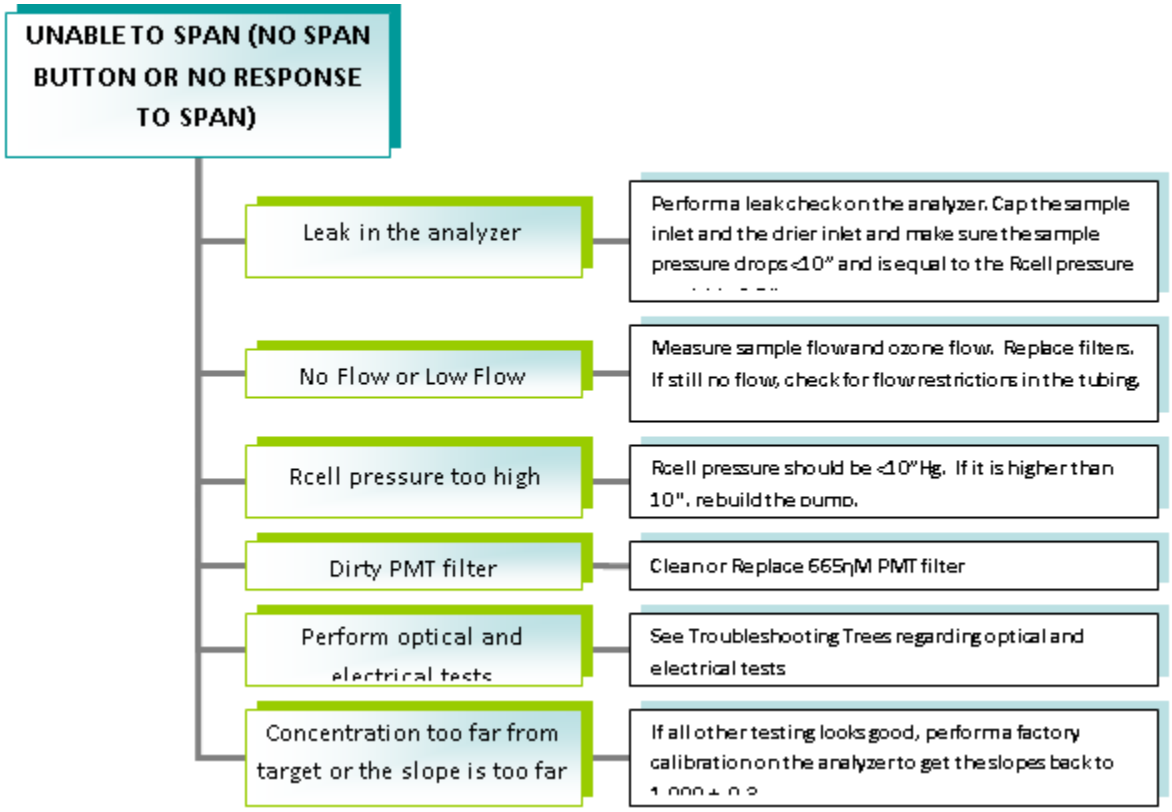


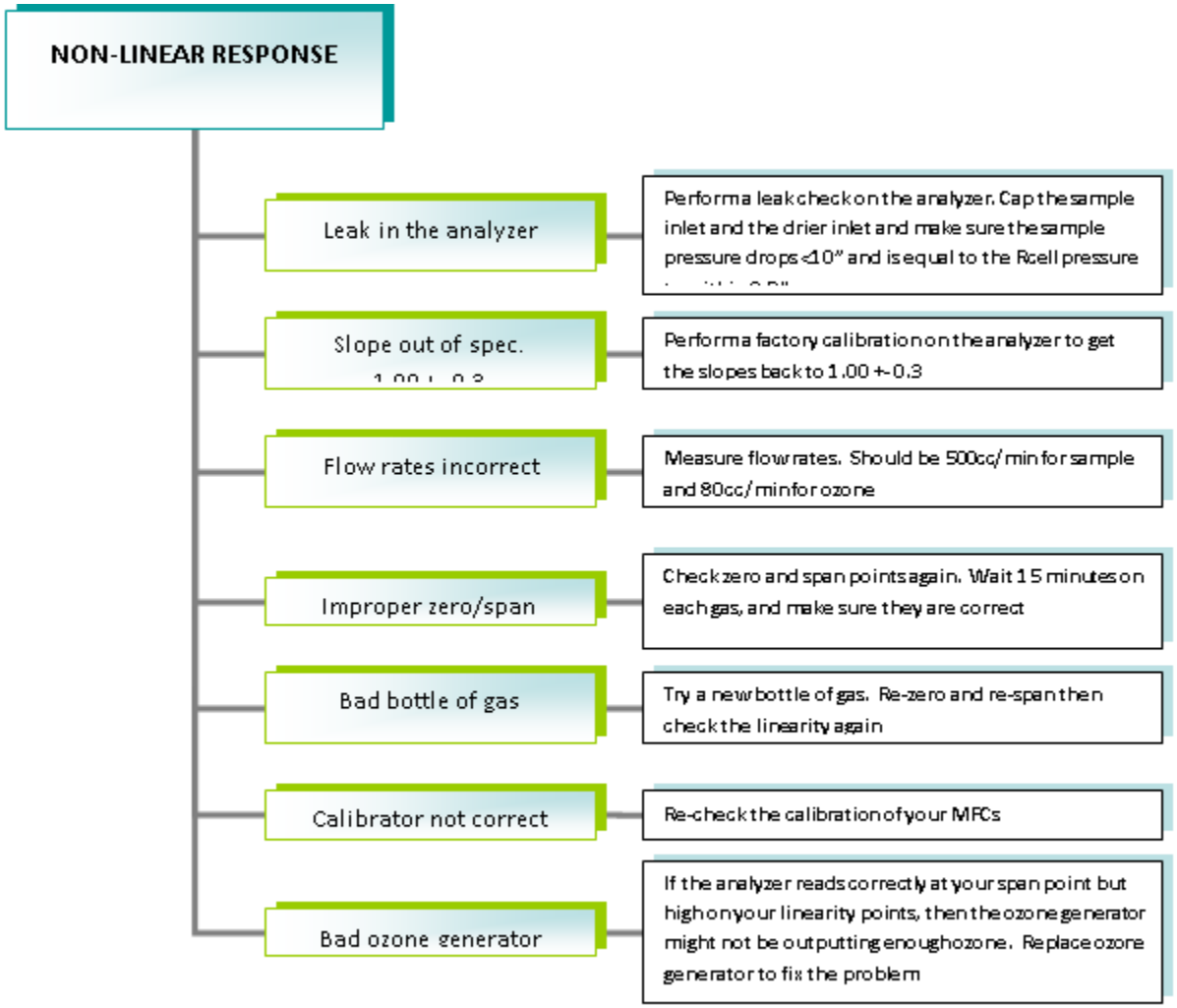


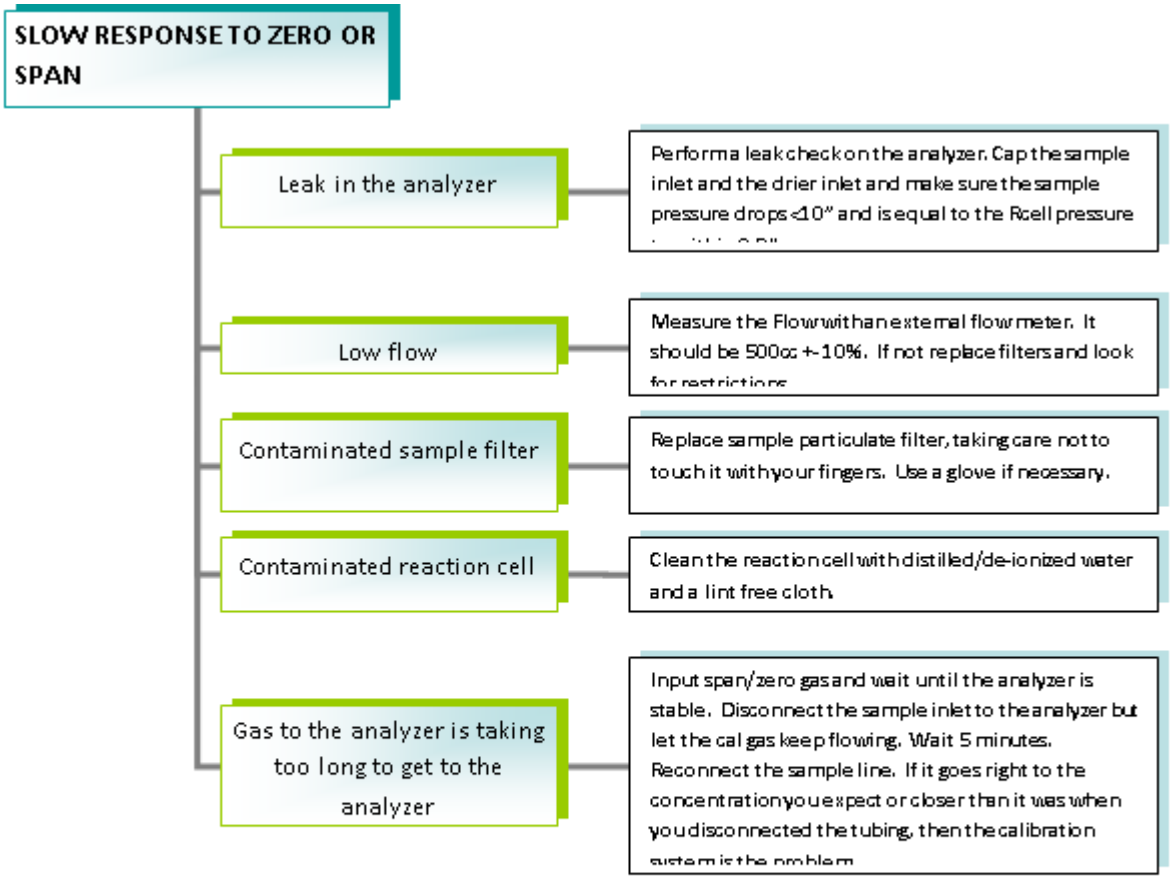


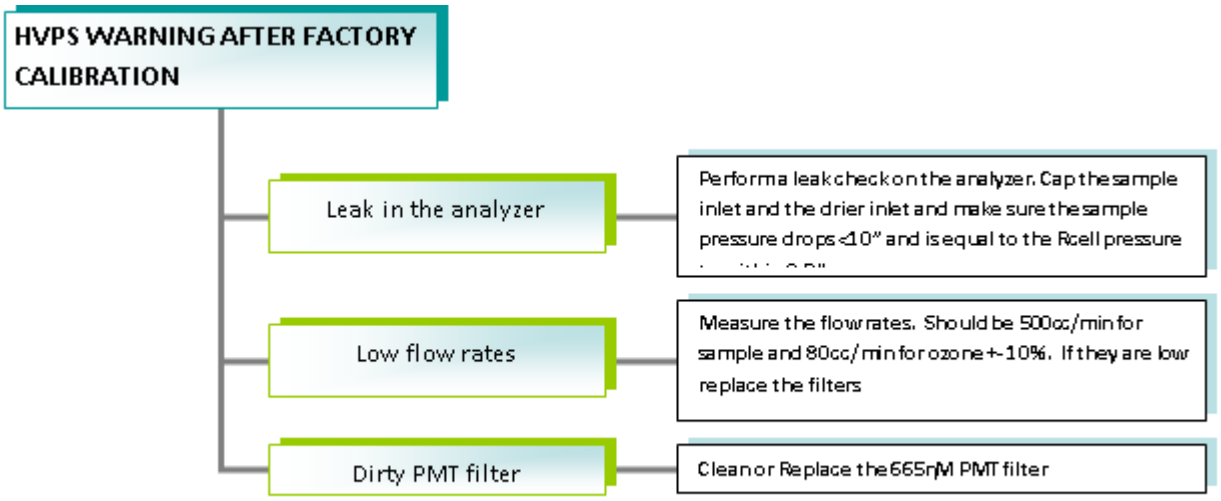


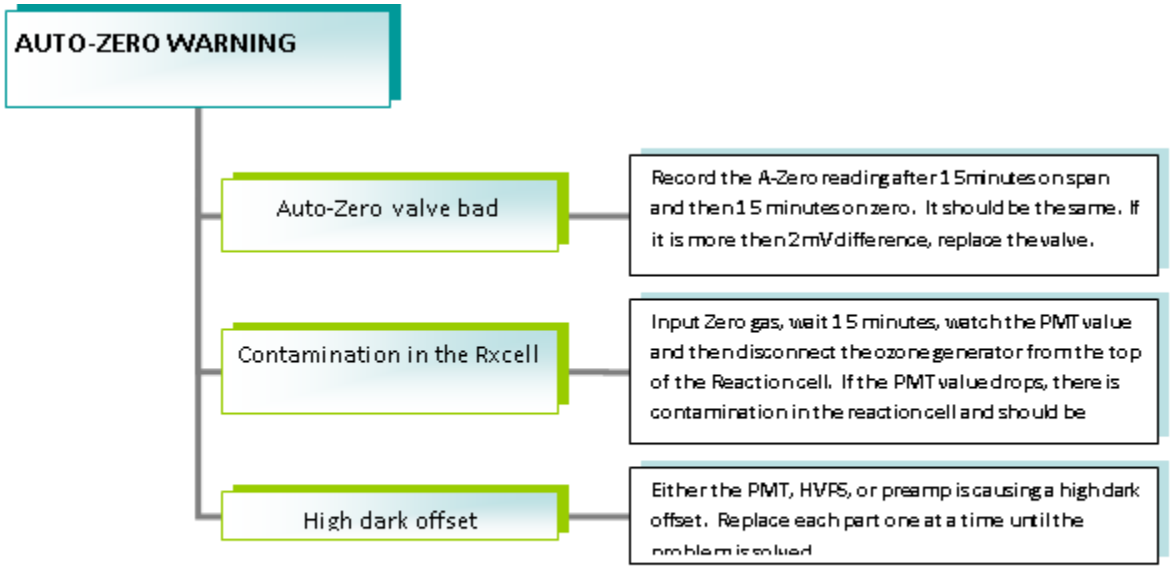


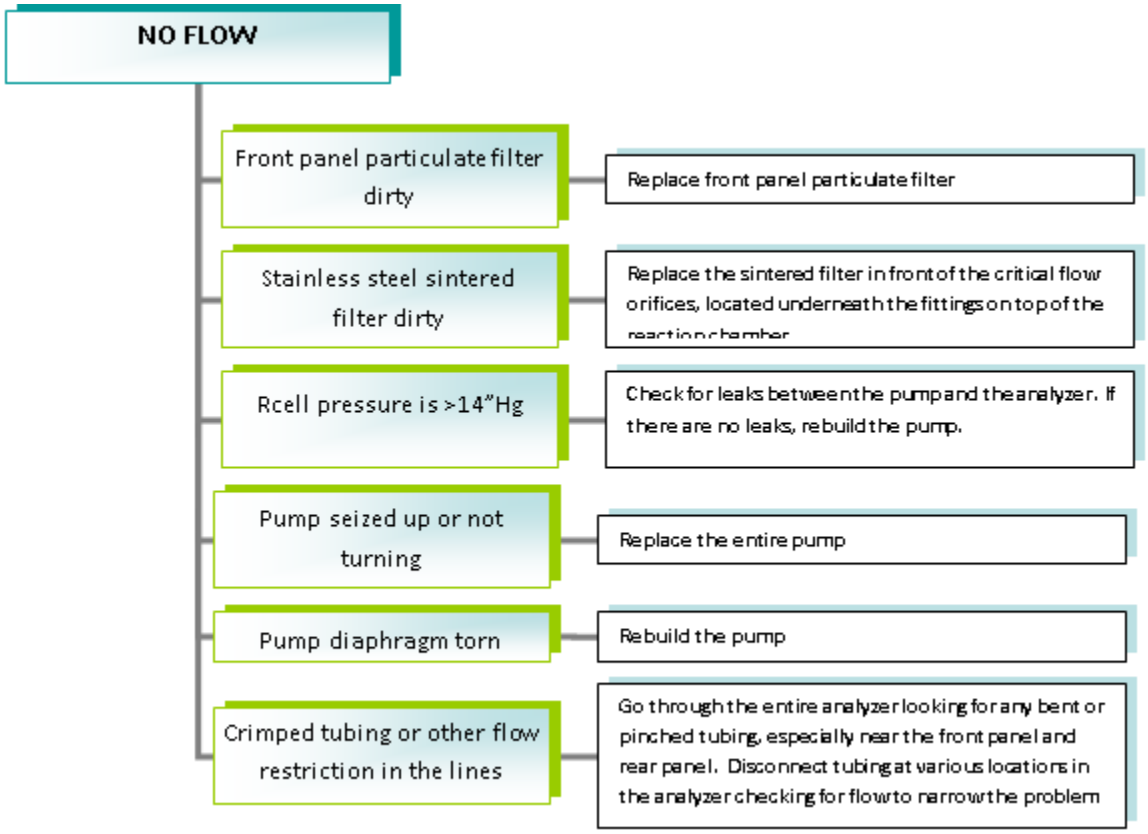


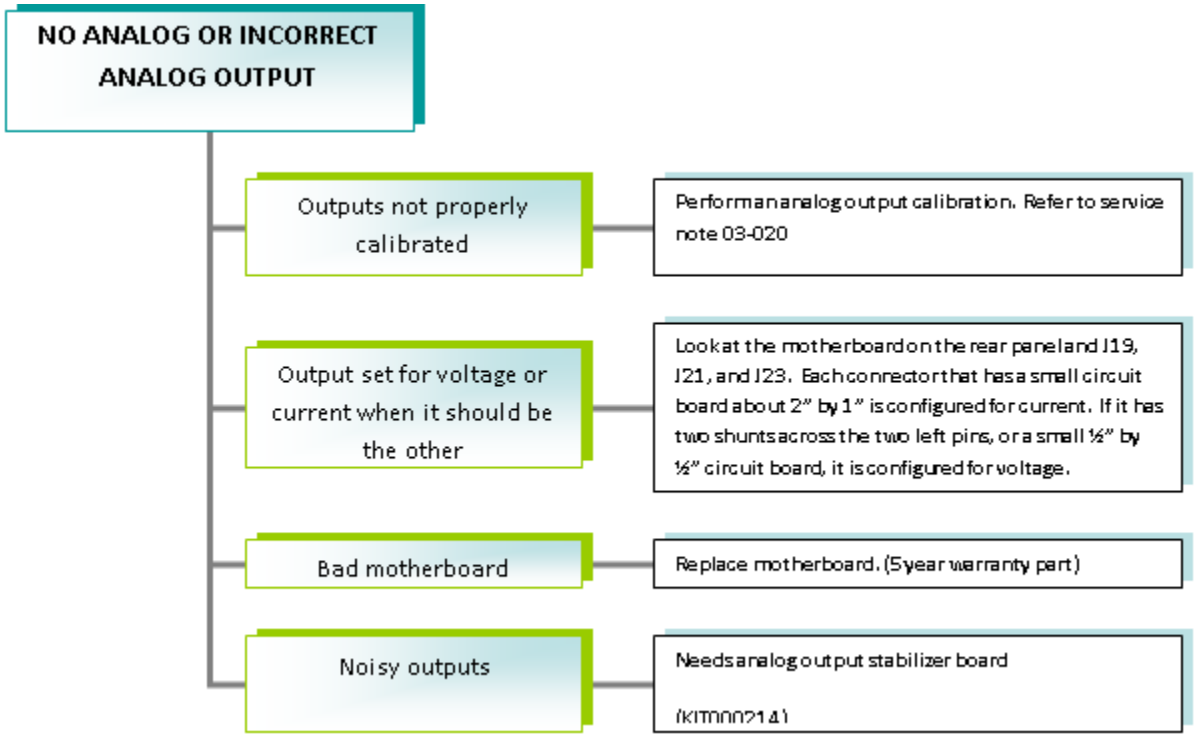


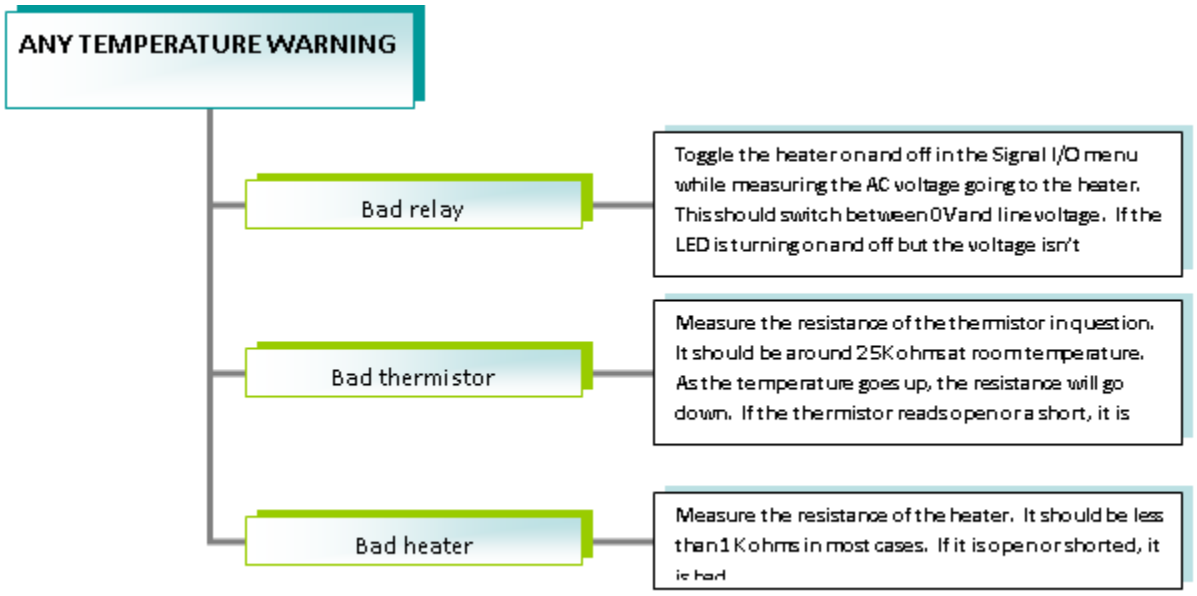












SPECIFICATIONS

Appendix C Warranty/Repair Questionnaire T204 (08156A, DCN6900)	TELEDYNE ADVANCED POLLUTION INSTRUMENTATION Everywhereyoulook™

CUSTOMER: _____ PHONE: _____

CONTACT NAME: _____ FAX NO. _____

SITE ADDRESS: _____

MODEL SERIAL NO.: _____ FIRMWARE REVISION: _____

1. ARE THERE ANY FAILURE MESSAGES? _____

_____

_____

PLEASE COMPLETE THE FOLLOWING TABLE: (**NOTE:** ***DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS SHOWN BELOW WILL BE AVAILABLE IN YOUR INSTRUMENT***)
*IF OPTION IS INSTALLED

PARAMETER	RECORDED VALUE	ACCEPTABLE VALUE
RANGE	PPB/PPM	50 PPB TO 20 PPM
O3 S/N		N/A
O3 READ	PPB/PPM	+/- 1% OF FULL SCALE RANGE WITH ZERO AIR
O3 STAB	PPB/PPM	≤ 4 PPB WITH ZERO AIR
O3 SLOPE		1.0 ± 0.15
O3 OFFS	PPB	± 20 PPB WITH ZERO AIR
O3 RNG	PPB	50 PPB TO 1000 PPB
O3 MEAS	MV	250 to 1230 MV
O3 REF	MV	250 to 1230 MV
O3CEL PR	PSIA	~.5 PSIA < AMBIENT (14.7 PSIA)
O3SAMP TMP	°C	AMBIENT ± 5°C
O3LMP TMP	°C	52 ± 2 °C
NOX STB	PPB/PPM	≤ 1 PPB WITH ZERO AIR
SAMP FLW	CM^3	500 ± 50
O3GEN FL	CM^3	80 ± 15
PMT SIGNAL WITH ZERO AIR	MV	-20 TO 150
PMT SIGNAL AT SPAN GAS CONC	MV PPB	0-5000MV 0-20,000 PPB
NORM PMT SIGNAL AT SPAN GAS CONC	MV PPB	0-5000MV 0-20000PPB
AZERO	MV	-20 TO 150
HVPS	V	400 – 900
RCELL TEMP	°C	50 ± 1 °C
BOX TEMP	°C	AMBIENT ± 5°C
PMT TEMP	°C	7 ± 2°C
IZS TEMP*	°C	50 ± 1°C
MOLY TEMP	°C	315 ± 5°C
RCEL	IN-HG-A	<10
SAMP	IN-HG-A	~ 1" < AMBIENT

Teledyne API Technical Support
EMAIL: SDA_techsupport@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

NOX SLOPE		1.0 ± 0.3
NOX OFFS	MV	-50 TO 150
NO SLOPE		1.0 ± 0.3
NO OFFS	MV	-50 TO 150
ETEST	PMT MV	2000 ± 1000
OTEST	PMT MV	2000 ± 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

2. WHAT ARE THE RCELL, SAMPLE & O3 CELL PRESSURES WITH THE SAMPLE INLET ON REAR OF MACHINE CAPPED?

RCELL PRESSURE -_____IN-HG-A **SAMPLE PRESSURE** - _____IN-HG-A **O3CELL PRESSURE**-_____PSIA

3. WHAT ARE THE FAILURE SYMPTOMS? _____

_____

_____

4. WHAT TEST(S) HAVE YOU DONE TRYING TO SOLVE THE PROBLEM? _____

_____

_____

_____

_____

_____

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.

Teledyne API Technical Support
EMAIL: SDA_techsupport@teledyne.com
PHONE: (858) 657-9800 TOLL FREE: (800) 324-5190 FAX: (858) 657-9816

DRAWINGS

AC POWER CONFIGURATION

The T204 analyzer's digital components 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,. Internally, the status LEDs located on the Relay PCA, Motherboard and CPU should turn on as soon as the power is supplied.

However, some of the analyzer's non-digital components, such as the various internal pump options or the AC powered heaters for the NO_2 → NO converter the reaction cell and some of the T204's must be properly configured for the type of power being supplied to the instrument.

Configuration of the power circuits is set using several jumper sets located on the instruments relay PCA.

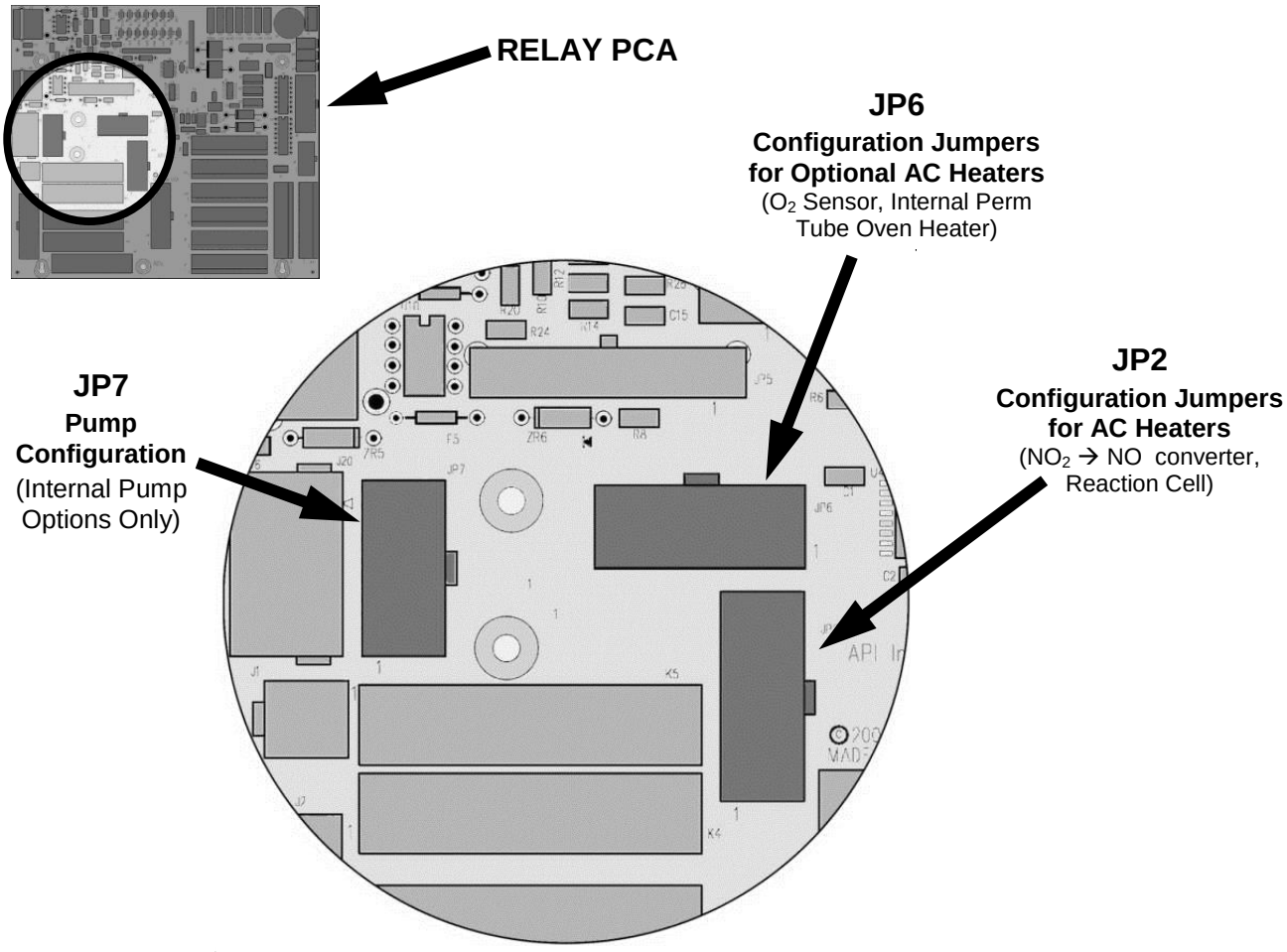


Figure Error! No text of specified style in document.**-1: Location of AC power Configuration Jumpers**

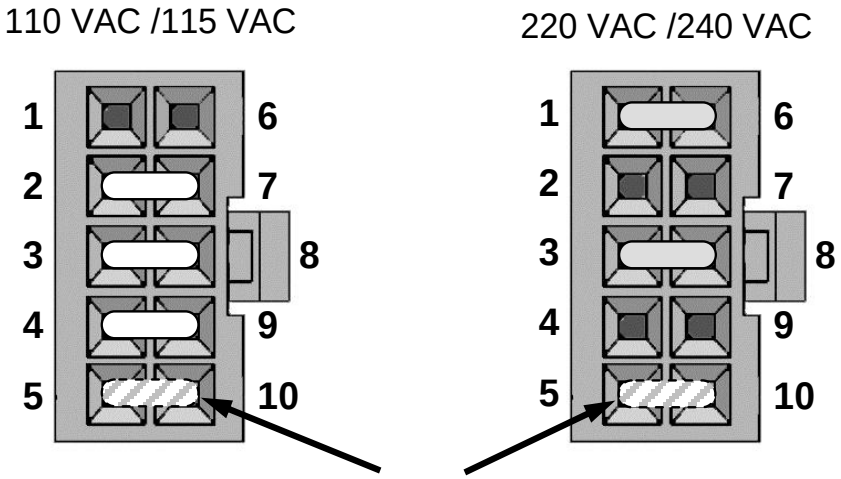
AC CONFIGURATION – INTERNAL PUMP (JP7)

If your T204 includes an internal pump the following table, jumper set JP7 is used to configure the power supplied to it as shown in **Error! Reference source not found.**.

AC Power Configuration for Internal Pumps (JP7)

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

[1] A jumper between pins 5 and 10 may be present on the jumper plug assembly, but has no function on the Model T204.



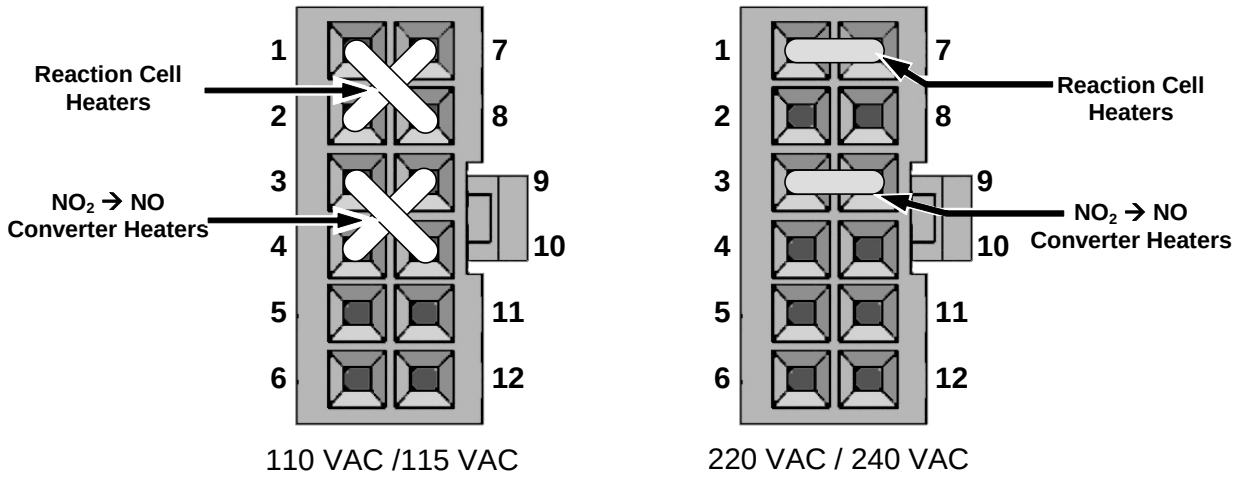
Pump AC Power Jumpers (JP7)

AC CONFIGURATION – STANDARD HEATERS (JP2)

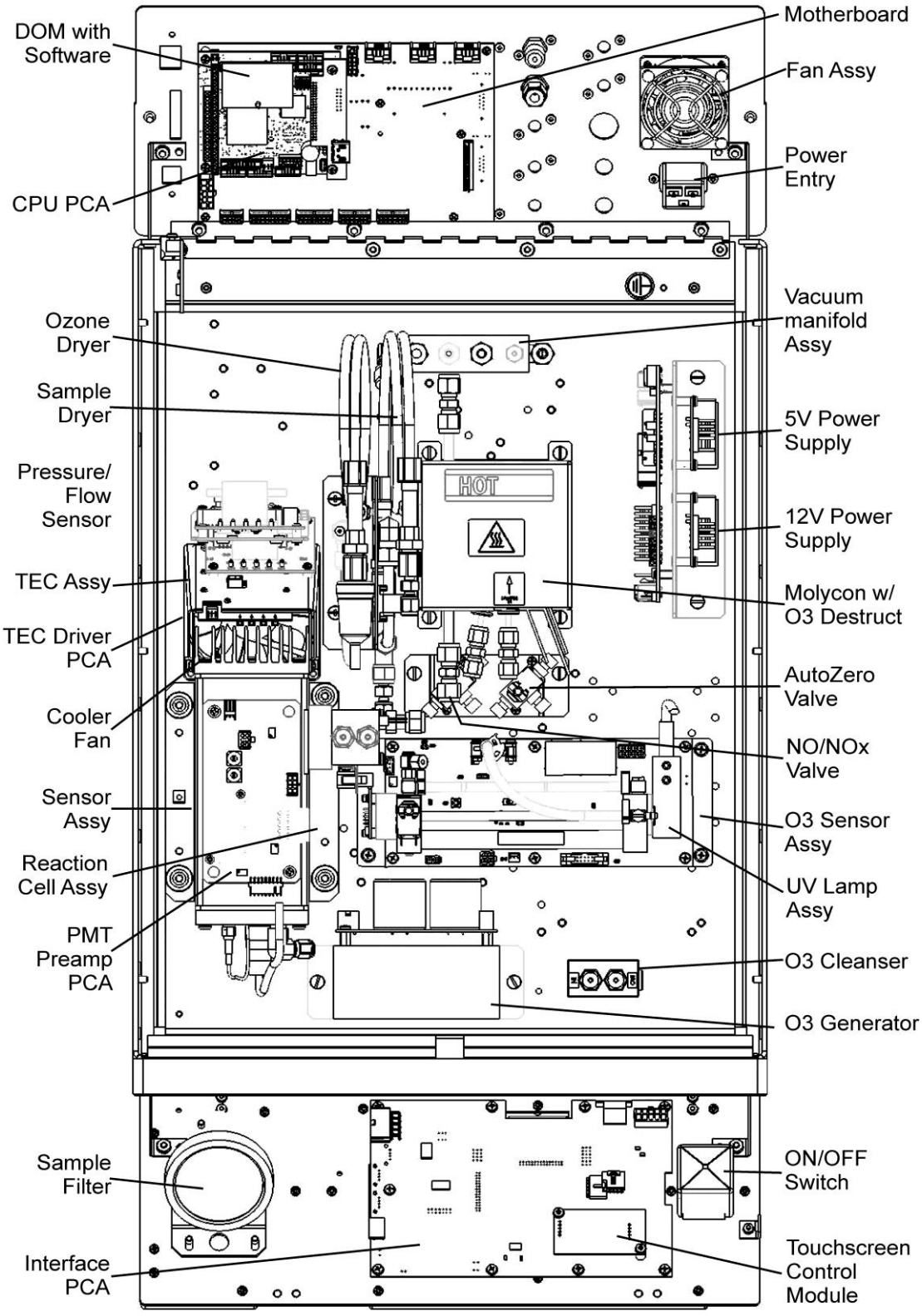
Power configuration for the AC the standard heaters is set using Jumper set JP2

Power Configuration for Standard AC Heaters (JP2)

LINE VOLTAGE	JUMPER COLOR	HEATER(S)	JUMPER BETWEEN PINS	FUNCTION
110 VAC / 115 VAC 50Hz & 60 Hz	**WHITE**	Reaction Cell / Sample Chamber Heaters	1 to 8	Common
			2 to 7	Neutral to Load
			4 to 9	Neutral to Load
		Moly Converter	3 to 10	Common
			4 to 9	Neutral to Load
			6 to 11	Neutral to Load
220 VAC / 240 VAC 50Hz & 60 Hz	**BLUE**	Reaction Cell / Sample Chamber Heaters	1 to 7	Load
		Moly Converter	3 to 9	Load

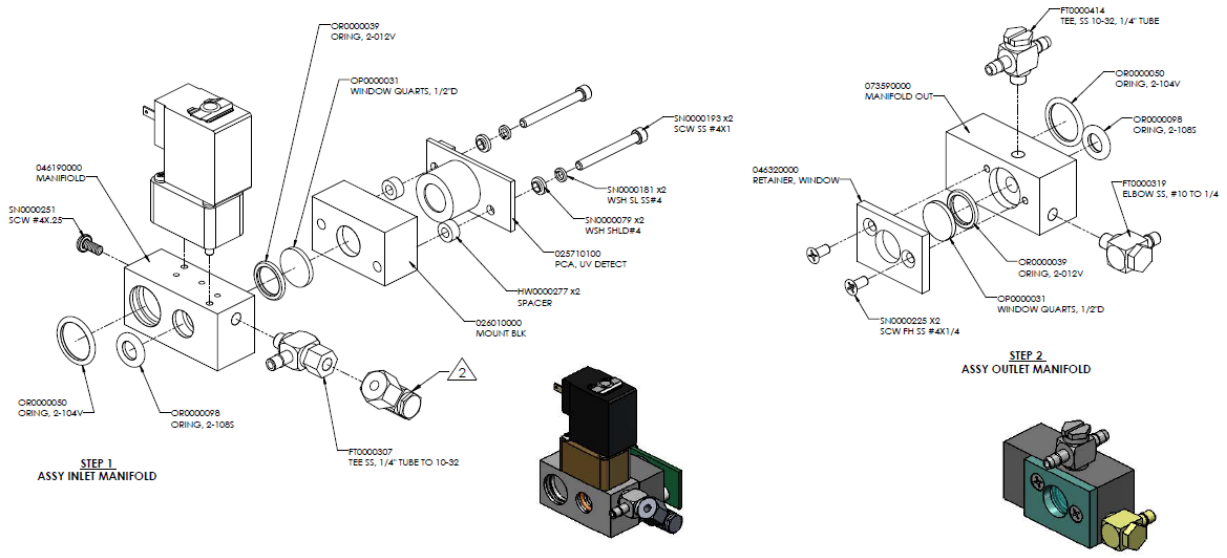


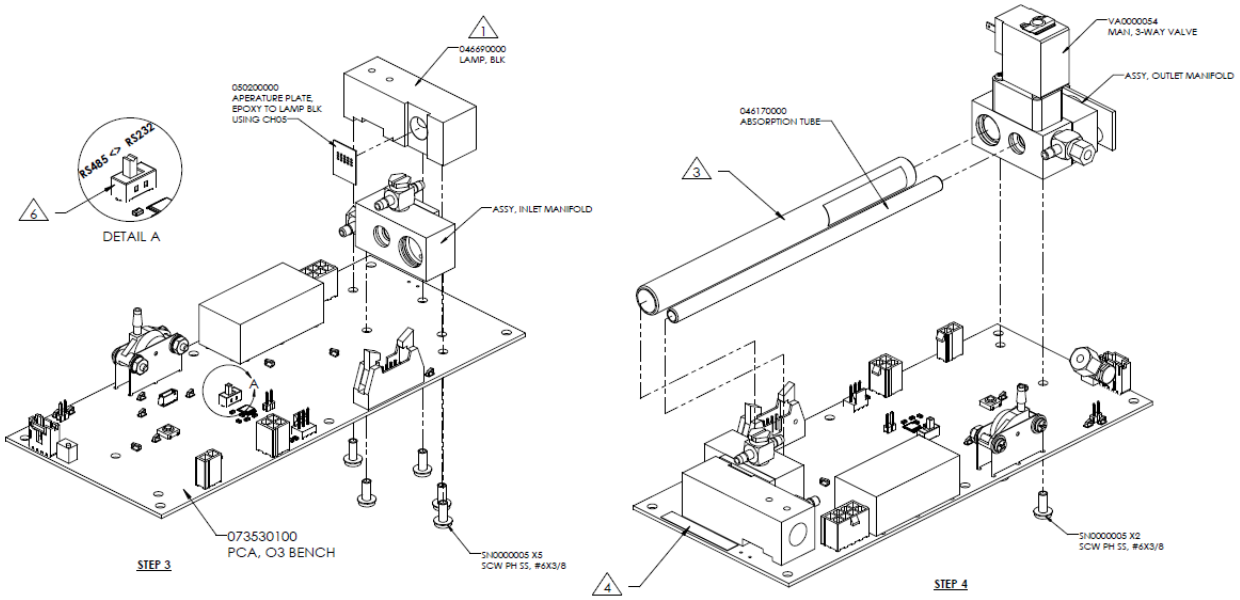
Typical Set Up of AC Heater Jumper Set (JP2)

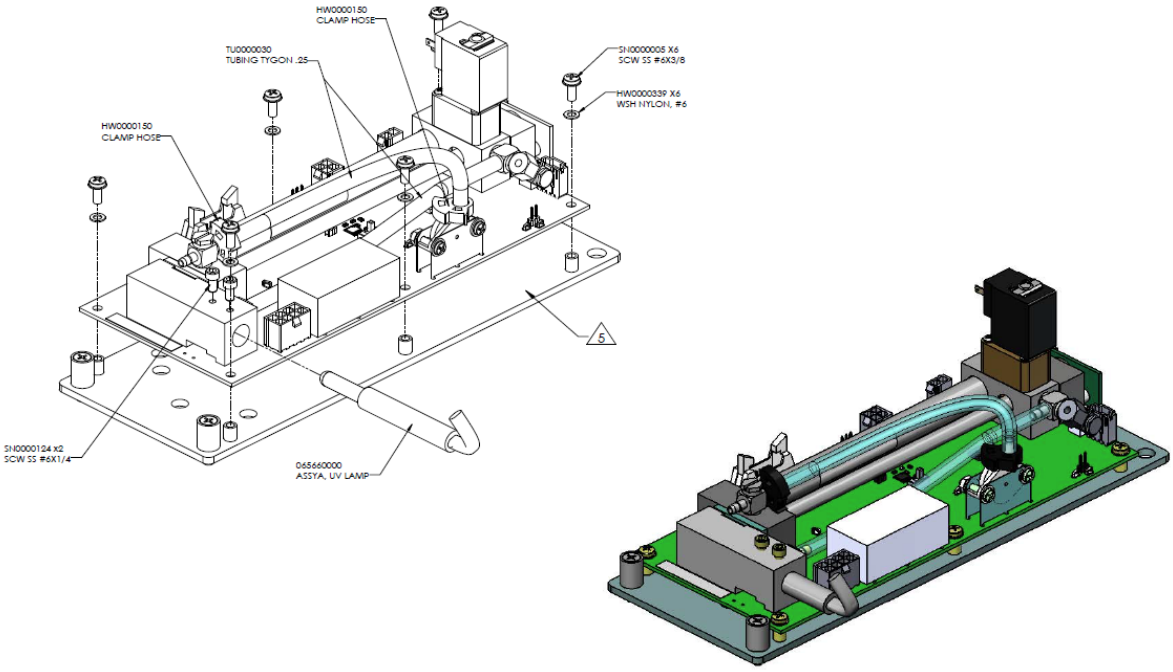


Internal Chassis Layout

O3 Sensor







Service Notes

10-020B T SERIES FIRMWARE UPDATE

10-021C T SERIES TOUCH SCREEN CALIBRATION

11-002A Installing a reference scrubber in a 465L NEMA Instrument

11-005B Troubleshooting a T series display

11-009A Installation of a Sample Conditioner into an M200E or T200 Analyzer

13-002B PMT Adjustment NOX

13-009A How to replace the TEC in SOX and NOX Analyzer

14-009A Troubleshooting T-Series with Analog and Digital Voltage Issues