Standard Operating Procedure

for

Routine Operation of the R&P Series 5400 Ambient Carbon Particulate Monitor

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2.29 SCOPE AND APPLICABILITY

The Series 5400 Ambient Carbon Particulate Monitor is capable of characterizing the carbon content of suspended particulate matter on an automated basis. The instrument performs a thermal CO_2 analysis to determine the amount of organic (OC) and elemental (EC) carbon (in $\mu g/m^3$) present in a collected particulate sample.

The Series 5400 monitor samples ambient air for one hour and then performs an analysis to determine the concentration of carbon in the collected sample. The 5400 has two collectors that operate in an alternating manner to avoid missing data during the analysis phase. A size-selective inlet with a 2.5- m cutoff is placed above the inlet of the Series 5400.

2.29.1 SUMMARY OF METHOD

The Series 5400 monitor employs a direct measurement approach to determine the concentration of carbon in particulate matter suspended in ambient air. Using a non-dispersive infrared (NDIR) CO_2 detector, the instrument measures the amount of CO_2 released when a sample in the collector is oxidized at elevated temperatures. This value is directly related to the amount of carbon oxidized in the collector and, together with the volume sampled, is used to determine the concentration ($\mu g/m^3$) of carbon in the ambient air during the sampling period.

The instrument cycle is composed of two main steps: 1) the collection phase where the sample is collected on an impaction plate within a "clam-shell" and 2) the analysis phase during which the collector and the particulate matter are elevated in temperature to achieve oxidation. The analysis phase takes approximately one hour for a procedure involving an intermediate and final temperature plateau. To avoid gaps in the collection of particulate matter, the instrument contains two collectors. While the monitor uses one for the collection phase of the current instrument cycle, the other is used for the analysis phase of the previous instrument cycle. To minimize the formation of unwanted artifacts during sample collection, the collectors consist of impactors instead of filters. It is important to note that the impactor has a "bottom-end" cut point of 0.14 µm. At the nominal flow rate of approximately 16.7 L/min, the lower particle size cut-point for the collectors is approximately 0.14 µm in diameter (D50). The default temperature of the collector is 50 °C during collection. During the analysis phase of the instrument cycle, the collector containing the particle sample becomes part of a closed gas-circulating loop that includes an afterburner, circulating pump, and the NDIR CO_2 sensor. Before raising the temperature of the collector, the instrument measures the CO_2 concentration in the closed analysis loop as a base line for later measurements. The temperature of the collector is then raised to 340 ^oC for a period of 480 seconds, during which the instrument measures the low-temperature carbon CO_2 concentration in the analysis loop. A final burn of 360 seconds at 750 ^oC then takes place to measure the high-temperature carbon that was not oxidized at the lower temperature. An afterburner, positioned immediately following the collector, heats the gas stream to 750 ^oC during the analysis phase to burn any lighter carbonaceous materials that may have escaped from the collector when oxidized. The instrument reports carbon concentration for the low temperature carbon, which is primarily composed of organic carbon, as MC3 in g/m^3. The total carbon concentration of the sample, composed of both elemental and organic carbon, is

reported as MCF in $\mu g/m^3$. The elemental carbon concentration is determined by the difference between the reported total and low temperature (organic) concentration.

At the end of each instrument cycle, the monitor purges the closed loop to prepare it for the analysis phase of the next instrument cycle performed using the other collector. During this step, it purges the closed loop with filtered ambient air taken through the inlet port on the back of the instrument. This purge reestablishes the concentrations of CO_2 and O_2 to ambient levels. The instrument measures the CO_2 concentration of the purge air and this value provides a estimate of the ambient CO_2 concentration.

2.29.1.1 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are based on the DQOs used for the Speciation Trends Network (STN). These are:

- Accuracy: LiCor CO2 sensor ± 10 %
- Precision: 15% CV (based on MQOs for the STN) as determined by replicate standards. .
- Completeness: At least 85% data completeness during designated intensive.

2.29.2 DEFINITIONS

All words typed in bold, capital letters throughout this document refer to labels on the instrument front or back panel.

DAS = Data Acquisition System

EC = Elemental carbon = Soot or black carbon = These terms are used interchangeably throughout the SOP. They all refer to pure carbon in contrast to carbon bonded to an organic molecule.

LPM = liters per minute

MSDS = Material Safety Data Sheets

OC = Organic Carbon = This term refers to molecules that contain a carbon backbone along with other elements, such as hydrogen, oxygen, or nitrogen.

OD = Outside Diameter

PPM = Parts Per Million

Soft keys = This term refers to the function keys (F1-F5) located just below the instrument display. These keys have various functions depending on the display screen.

SOP = Standard Operating Procedure

2.29.3 HEALTH AND SAFETY WARNINGS

The R&P5400 operates on high voltage, 240 VAC. Exercise extreme caution when maintaining or repairing any component of the instrument. High voltage may be present in all instrument enclosures.

The inside of the instrument contains many hot surfaces because of the high temperatures used in the analysis. Be careful not to touch any of these surfaces.

High-pressure gas cylinders are used to calibrate the R&P5400. Make sure the tanks are properly secured at all times. Read all MSDS that come with these gases.

Safety glasses should be worn when working with high-pressure gas cylinders.

2.29.4 CAUTIONS

The user must take extreme care to ensure that no foreign matter is permitted to drop into the instrument by way of the sample tube inlet on the top of the instrument. Always cover this opening when it is not connected to the sample tubing.

Inside the instrument enclosure, most of the instrument components are mounted on a bulkhead, which is attached to rails at its top and bottom. The user can slide the bulkhead out of the enclosure to facilitate maintenance and service activities. The user must attach the service support brackets provided with the monitor before sliding out the bulkhead. Failure to do so may result in the instrument tipping over. The R&P5400 must be installed in a weather-sheltered location that is kept at a moderate temperature at all times. The monitor must be placed in a well-ventilated position. The R&P5400 requires a dedicated circuit with a minimum of 15 Amps, 240 VAC and a separate 120 VAC circuit to power the pump. If the line voltage is less than 230 VAC, R&P recommends using a step-up transformer.

VERY IMPORTANT! Make sure the service legs have been installed on the unit exterior prior to performing any maintenance activities that require pulling out the bulkhead. Also, always wear anti-static devices when working with the system electronics.

When **USING A DATA LOGGER** it is important to note that there is a 2-hour delay in transmission of the data from the 5400 to the data logger due to the dual-channel, alternating sampling and analysis. If you are using the output from a data logger, it is very important to adjust the data start time stamp by 2-hours (earlier) to account for the delay. For example, the 5400 collects sample from 5-6 am and then goes into the analysis step from 6-7 am. Following the analysis at 7 am the data will then be sent to the data logger and will include a 7 am time data logger stamp. Since this data was actually collected starting at 5 am, the time stamp would need to be adjusted from 7 am to 5 am.

2.29.5 INTERFERENCE

The R&P5400 requires at least 236 VAC power to operate properly. If this power requirement is not met, the afterburner temperature will not attain the set point. In addition to generating an instrument error, this problem will throw off the timing of the cycles.

2.29.6 PERSONNEL QUALIFICATIONS

This SOP along with the instrument operating and maintenance manual should be adequate in training personnel to operate the 5400 Ambient Carbon Particulate Monitor.

2.29.7 APPARATUS AND MATERIALS

- Series 5400 complete with pump and accessories package.
- Cyclone with 2.5 m cut-off for the inlet. Generally this is achieved with a PM_{10} impactor mounted in series with a $PM_{2.5}$ cyclone.
- Calibration gas cylinders: CO_2 free air, low concentration CO_2 in nitrogen (e.g., 2200 ppm ± 1%), high concentration CO_2 in nitrogen (e.g., 4500 ppm not to exceed 5000 ppm ± 1%).
- Low-pressure regulators for each of the three gas cylinders (e.g. Matheson 8-2-590 and 8-2-580).
- Flexible 3/8" O.D. tubing to connect the gas cylinders to the back of the instrument.
- Approximately 20 feet of 3/8" O.D. green flexible nylon tubing to connect ambient air to the back of the instrument to purge the closed loop at the end of each instrument cycle.
- Approximately 20 feet of conductive (e.g. metal or conductive polymer), 1/2" O.D. tubing to pipe outside ambient air into the top inlet of the analyzer for particulate analysis.
- A data acquisition system or mechanism to download data through the RS232 port
- Data cables to connect the Series 5400 to the data acquisition system or laptop.
- A voltmeter, various wrenches, hex keys, screwdrivers, and a tube cutter.
- Digital voltmeter capable of reading to 0.001 VDC
- Gas Cylinder wrench (large)

- Adjustable rotometer for controlling gas flow (@1L/min) from cylinders
- Burner remover tool (R&P part no.30-003033)
- Flow Audit Adapter (R&P part no.57-000618)
- Volumetric Flow Meter capable of reading 0.1 L/min

2.29.8 SITE AND EQUIPMENT PREPARATION

- Off site equipment acceptance
  - Inspect the instrument for any damage. Remove all protective plugs from the fittings on the rear and top of the instrument and look for any indications of damage.
- Off-site pre-deployment equipment test
  - Locate the in-line filter assembly with the clear blue casing. One end of the filter should have a male, quick-disconnect fitting and the other, a plastic, push connector. Attach the quick disconnect fitting on this filter to the inlet labeled **AIR** on the back of the instrument. Note that the arrow on the side of the filter indicating the direction of flow is actually pointed in the opposite direction. Air will flow into the instrument from this port, opposite the direction of the arrow. Attach the 20 feet of 3/8" O.D. green nylon tubing to the push connector on the other end of the filter assembly. To remove this tubing for any reason, push in on the ring around the tubing while pulling out the tubing. Run this length of tubing through the ceiling or to the manifold for access to the outside air. Make sure that there is no possibility of water entering the tubing.
  - The second segment of green nylon tubing is used to connect the pump to the R&P5400. One end of the tubing should be inserted into the push connector outlet on the back of the instrument labeled **PUMP**. The other end should be inserted into the push connector inlet on the pump.
  - The three gas cylinders used for calibrating the Series 5400 must be plumbed to the instrument. The gas cylinders must be secured to the wall or table for safety. The gas regulators should be attached to each of the cylinders. Each of the outlets of the gas regulators should have a hose barb fitting on it. The inlets on the back of the R&P5400 labeled **N2**, **CO2 HIGH**, and **CO2 LOW**, have female quick disconnect fittings. Find the male counterparts to these fittings, which have hose barbs on the other end, and connect them to each of the inlets. Connect 3/8" O.D. flexible tube from the hose barb fitting on the regulator to the hose barb fitting on the back of the 5400.
  - Check the connections for leaks using the following method. Open the main valve of the regulator and adjust the delivery pressure to 2.5 psig. Close the main valve, wait

2 hours and observe the delivery pressure reading. Check connections and fittings if the pressure has dropped below 2.4 psig.

- Plug the 5400into an appropriate 240 VAC/15 Amp outlet.

- Turn on the instrument and allow it to warm up for 30 minutes. Do not turn on the pump at this time.

- Turn on the pump by plugging it into an appropriate 120 VAC electrical outlet. Note: Do not plug the pump into the same circuit as the DAS.

- Setup the operating parameters using the Run Definition Screen, which can be entered by pressing the **F3: RunDef** softkey while in the Main Screen. Depress the **EDIT** key and edit the Run Definition Screen to display the following information. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

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Run Definition Example

Coll. Time	1 Hr	P1	0 C	D1	0 Sec
Coll. Temp	50 C	P2	0 C	D2	0 Sec
Aburn Temp	750 C	P3	275 C	D3	480 Sec
Ext. Temp	0 C	P4	750 C	D4	240 Sec
Coll. Flow	16.7lpm				

- The protocol defined above will measure carbon on a 3-hour schedule in two burns (P3 and Pf), with dwell time of 8 and 6 minutes. Note the aerosol sample is heated to 50 °C (Coll Temp: 50 C) so the sample will remain below the dew point temperature. Applying insulation or mildly heating the inlet line will also keep the sample from condensing onto the internal hardware in a humid environment.

- From the main screen, set up additional operating parameters by pressing the **F5: Setup** soft button. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

A/S Temp: 25 25
A/S Pres: 1.00 1.00
Smoothing? NO

Audit Freq: 71 cyc
Leak Check: 0 cyc
Audit Limit: 10%

Curr Time: 17:14:55
Curr Date: 27-Aug-01

- Note that the above setup references sample flows, volumes, and concentrations to 25 °C and 1 atm pressure. Determine seasonal average temperatures for your

location and edit the temperature. An audit frequency of 0 disables automated audits of the CO_2 sensor. Automated calibrations should be attempted only after verifying that the gas delivery system has no leaks and that the audit results are stable. After verifying integrity of the audit system, set the cycle for audit checks to 57 (once per week; odd number to allow for audit using alternating collectors). Smoothing, which provides measurements that are the average of the current and last readings will not be used for the continuous speciation study.

- Check the software version and serial number for your instrument. In the Main Screen, press **F5:Setup** and then press **F3:System Info**. Note the entries in the instrument log.

  Software Version: 1.71, August 3, 2001
  Unit Serial Number: XXXXX

- Note: The unit should be operated with the most recent version of R&P software. Contact R&P if the instrument displays an earlier software revision. Updated software can be downloaded from the R&P web site.

- Check that in the analog conversion variables are correct. In the Main Screen, press **F5:Setup** followed by **F1:Output** and **F1:A/O**. Set the parameters to the following values. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

	Variable	MinVal	MaxVal	Format
1	MC 3	0.00	50.00	0-5 VDC
2	MC Final	0.00	50.00	0-5 VDC
3	Purge CO2	0.00	5000	0-5 VDC

- Setup the communications parameters to allow automatic downloading of data from the 5400 to the DAS. In the Main Screen, press **F5: Setup** followed by **F1:Output** and **F2:RS232**. Set the parameters to the following values. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

Protocol:	Cycle	RS-Para1:	52
Baud Rate:	9600	RS-Para2:	75048
Data Bits:	8	RS-Para3:	13010
Parity:	None	RS-Para4:	0
Stop Bits:	1	RS-Para5:	0
Flow Ctrl:	None	RS-Para6:	0

- Setup the parameters to be sent from the 5400 to the data acquisition system you are using. In the Main Screen, press **F5: Setup** followed by **F1:Output**, **F2:RS232**, and **F2:SET PRC**. Set the parameters to allow system to work with your particular

DAS. See Appendix B of the user manual for a complete listing of system parameters. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits. **The values listed below are provided as an example only.**

Data1:	Stat Code (6)	Data7:	Set Flow (77)
Data2:	MC3 (109)	Data8:	Samp Vol (117)
Data3:	MC Final (110)	Data9:	0
Data4:	ABurnA SP (61)	Data10:	0
Data5:	ABurnB SP (62)	Data11:	0
Data6:	Std Flow (75)	Data12:	0

- Record all of the settings that were just entered into the instrument log as they are shown on the displays. Make a photocopy of the settings and archive for future reference.

- Escape back to the Main Screen and press the **RUN/STOP** key if instrument is running. Press the **MENU** key and select **Service Mode** then **Instrument Setup**. Record information displayed for System Volume and CO_2 Sensor in the lab notebook. Ensure that the sensor type is correct; possible values for this field are "LiCor" (LiCor linear), LiCoPres (LiCor linear with pressure compensation) or LiCorCom (LiCor linear with pressure compensation connected via RS232). Also ensure that the CO2 low and CO2 high values reflect the concentration of your calibration gas cylinders.

Instrument Setup

Valve Type: Pinch w/o offset
System Volume: 108 µl
Oven Type: Carlo Gavazzi
CO2 Sensor: LiCorCom
CO2 Sensor Span: 5000 ppm
CO2 low: ~1500 ppm (match to your specific tank value!)
CO2 high: ~4000 ppm (match to your specific tank value!)

- While in the service mode, press the up and down arrow keys to select **Calibration/audit** and press F2: CO2 Cal. Record all information from the CO2 calibration/audit screen.

- The latest version of LiCor CO2 sensor software is 1.7.1, dated August 3, 2001

- Enter Edit mode using the **EDIT** key and change the CO_2 Low % and CO_2 High % to match the concentrations on the calibration tanks. Note that 400 ppm and 2500 ppm equate to 0.040% and 0.250%, respectively. Press **ENTER** to save edits and press

ESC to exit Service Mode.

- Perform instrument calibrations as outlined, and in the order presented in Section 12.3, of the Operations Manual. These procedures are also listed in **Table 8-1** below. Skip the CO_2 Calibration - Manual and CO_2 Calibration - Hardware. Record the original and final settings, and the findings of each of the procedures in the instrument logbook. Save the calibration constants and make a note of them in the instrument logbook. NOTE: The mass flow meter calibration simply adjusts the display value to match the readings from the calibration device. It does not adjust the flow set point for the instrument. Flow through the Model 5400 is actually 'controlled' by the geometry of the impactors. Flow may start out near 17.5 LPM for new collectors, and decline over time as non-volatile material accumulates. Collectors should then be replaced when flow goes below the tolerance for the inlet device.

- Audit the 5400 by completing the procedures listed in **Table 8-2** after the calibration procedures shown in **Table 8-1** are complete.

Table 8- 1 Audit and calibration procedures for the R&P 5400 to follow in order to check system after receipt.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Analog I/O Calibration – Software	3.1 (Service Manual)	5
2.	Analog I/O Calibration – Hardware	3.2 (Service Manual)	5
3.	Collection Path Leak Test	4.6	5
4.	Flow Audit	4.4	5
5.	Flow Meter Calibration	3.5 (Service Manual)	10
6.	Analysis Loop Leak Test	4.5	25
7.	Temperature Circuit Calibration	3.7 (Service Manual)	25
8.	CO2 Calibration – Automatic	12.3.1	25
9.	Furnace Calibration	12.3.3	10
10.	Storage of Calibration Data	10.12	5

Table 8- 2 Audit and calibration procedures the R&P 5400 OC/EC instrument to be followed prior to collecting data.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	1st follow-up CO2 Calibration – Automatic	12.3.1	25
2.	2nd follow-up CO2 Calibration – Automatic	12.3.1	25
3.	1st follow-up CO2 Calibration – Audit	12.3.1	25
4.	2nd follow-up CO2 Calibration – Audit	12.3.1	25

- Upon completion of all of the tasks in **Tables 8-1** and **Table 8-2**, depress the **Data** key to access calibration and audit results. Note that calibrations are denoted with AC (Automatic Calibration) and audits are denoted with AA (Automatic Audit), and that they are displayed most recent on top. Check that the constants C1, C2 and C3 for the calibrations and audits are as noted already in the instrument logbook. Calculate observed tank concentrations as shown below.

  Zero air (ppm) = C1*Sys Volume*10^{-6}
  CO2-Low (ppm) = C2*Sys Volume*10^{-6}
  CO2-High (ppm) = C3*Sys Volume*10^{-6}

  Compare the observed and actual tank concentrations for the final calibration and two audits. Mean concentrations should be within the acceptance ranges shown below. Note that it may be necessary to use results from the last two audits if results from the first deviate significantly (>10 ppm or >±5%) from succeeding audits.

  Zero air (ppm) ± 15 ppm
  CO2-Lo (%) ± 10% of actual tank concentration
  CO2-High (%) ± 10% of actual tank concentration

- Repeat the CO_2 Sensor Calibration if the acceptance criteria are not satisfied.

- Operational Testing. After completion of steps above, the instrument is ready to begin collection of data for operational testing. This mode of operation should last anywhere from four to seven days, but the longer the better.

- Exit the Service Mode and press the **Run/Stop** key. The unit should begin a cleaning cycle at this point and will display CLEAN in the upper right hand corner of the Main Screen. Turn on the sample pump. The instrument will begin sampling at the top of the next hour, provided the cleaning cycle is completed. Otherwise, it will wait until the next hour. Observe the instrument as it goes into sample mode. Verify that sample flows are nominal and that no status conditions are displayed. Observe 1-2 additional sample cycles to ensure proper operation.

- Allow the unit to run in automated sampling mode overnight until the next work period.

- Perform the operational tests listed in **Table 8-3** on the instrument for 3 sequential days (at minimum). Press the **Run/Stop** key to enter Service Mode. Record audit/check results and the two most recent constants C1, C2 and C3 in the instrument log book. Contact R&P if the unit fails the collection loop or analysis loop leak checks.

Table 8- 3 Audit procedures for the R&P 5400 instrument to be followed three consecutive days after acceptance.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Collection Path Leak Test	4.6	5
2.	Flow Audit	4.4	5
3.	Analysis Loop Leak Test	4.5	25
4.	1st follow-up CO_2 Calibration – Audit	12.3.1	25
5.	2nd follow-up CO_2 Calibration – Audit	12.3.1	25

- Exit the Service Mode and escape back to the Main Screen. Depress the **Run/Stop** key to allow the 5400 to return to clean then sample mode.

- Audit data review. Compare audit results with the acceptance criteria listed below. Recalibrate the mass flow meter and/or the CO_2 sensor if acceptance criteria are not satisfied. Note that the results of the first CO_2 sensor audit may be rejected if not within tolerances.

  Zero air, CO2-Low, CO2-High: ± 5% of actual tank concentration
  Flow Audit: Indicated Flow = Flow Cal. Device ±5%
  Note: Flow cal. device must be corrected to mass if volumetric

- Data Review. Set Point data should be transferred into a spreadsheet program (e.g., EXCEL) for review on a daily basis. Key variables for review are: purge CO2 concentration, MC3 (organic carbon), MCF (total carbon), MCR3 (MC3 residual carbon) and MCRF (MCF residual carbon). There are no ironclad rules for acceptance of these data; however, they should satisfy a number of checks, as noted below.

  CO_2 Variability. Continental background CO_2 concentrations are on the order of 350 ppm. Unless the monitor is located in an urban core site, or extreme stagnation prevails, CO_2 concentrations could approach 350 ppm. Lowest concentrations (i.e.< 400 ppm) should occur during sunny, well-ventilated afternoons. Highest concentrations (i.e., >500 ppm) may occur during rush hours, nocturnal inversions, or as the result of nearby forest fires or wood burning. In any case, the general

pattern should be one of lower concentrations during daylight hour than during nighttime hours. Contact R&P if CO_2 variability is not observed, or if CO_2 concentrations never fall below 400 ppm.

OC/EC Variability. Continental background concentrations of OC and EC are on the order of 0.5-1 g/m^3 and 0.05-0.2 g/m^3, respectively. Under normal conditions, OC and EC will tend to vary with CO_2 concentrations. Under well-ventilated conditions, OC and EC should go below 2.0 g/m^3 and 0.5 g/m^3, even at urban sites. During rush hour or under nocturnal inversions, OC and EC can exceed 10 ug/m3. This should be the case, if CO_2 levels exceed 500 ppm.

OC/EC Ratios. OC:EC ratios will generally be on the order of 3:1 to 4:1, but may approach 1:1 if diesel emissions or other sources with appreciable EC content are significant.

MCR3 and MCRF Values. These are the concentrations derived from the residual burn stages. As noted earlier, they appear to reflect pressure/temperature changes in the CO_2 sensor, rather than bona fide CO_2 produced from combustion. MCR3 and MCRF should always be positive and on the order of 1-3 ug/m^3. They should be relatively invariant, as a function of the purge CO_2, OC and TC. For example, variability in MCR3 should be less than 5 percent of the variability in OC. Although less certain, field data suggest that MCR3 should be about 75 percent of MCRF. Negative values or values above 5 ug/m^3 may indicate a problem with the CO_2 sensor and should be reported to R&P.

- On-site equipment acceptance
  - The same procedure should be followed on-site as was followed off-site.
- On-site equipment installation
  - The R&P5400 will be placed on a sturdy table near a 240-volt power receptacle. The table should be at least 36” deep to permit the instrument bulkhead to be extended for maintenance and calibrations.
  - The inlet tube on the top of the instrument should run directly upwards through the ceiling of the monitoring building. The inlet tubing should be as straight as possible and should not have any severe dents in it. Irregularities in the tubing may result in particles depositing on the tube walls.
  - Attach 3/8” OD aluminum tubing to the top of the instrument and connect the cyclone to the top of the inlet. The cyclone should sample the ambient air at approximately six feet above the top of the roof.
  - Vent the furnace gases outside of the building and away from the roof. The furnaces release enough heat to warm a 30-foot trailer. This increase of temperature might be

difficult for the trailer heater to handle during cold seasons and has been seen to cause deficiencies in the operation of other instruments (i.e., TEI 42C/Y NOy instrument).

- Optional: Under hot, humid conditions, condensation can occur in the sampling line as the sample gas passes through the air conditioned environment of an air monitoring station. As a precaution, the inlet tubing should be insulated. Pipe insulation is commonly available at hardware stores.

- On-site connection of equipment to data acquisition system

  - The Series 5400 is connected to the DAS using the RS232 port located in the lower left of the front of the instrument. The instrument has a nine-pin female port, and thus requires a nine pine male connector.

- On-site connection of equipment to calibration system

  - External calibration system not used with 5400.

- On-site equipment test

  - The same procedure as was followed off-site should be followed on-site.

2.29.9 INSTRUMENT OR METHOD CALIBRATION

The R&P5400 instrument will be audited on a monthly basis by following the tasks listed in **Table 9-1**.

Table 9 - 1 Audit procedures for the R&P 5400 OC/EC instrument.

Task	Audit/Calibration Procedure	Operating Manual Section	Approximate Time (mins)
1.	Collection Path Leak Test	4.6	5
2.	Flow Audit	4.4	5
3.	Analysis Loop Leak Test	4.5	25
4.	1st CO2 Calibration – Audit	12.3.1	25
5.	2nd CO2 Calibration – Audit	12.3.1	25

The 5400 will be calibrated on a quarterly basis by following the tasks listed in **Table 9-2**.

Table 9 - 2 Calibration procedures for the R&P 5400 OC/EC instrument.

Task	Audit/Calibration Procedure	Service Manual Section	Approximate Time (mins)
1.	Analog I/O Calibration – Software	3.1	5
2.	Analog I/O Calibration – Hardware	3.2	5
3.	Flow Meter Calibration	3.5	10
4.	Temperature Circuit Calibration	3.7	25
5.	Furnace Calibration	12.3 (Operating Manual)	10
6.	Storage of Calibration Data	10.12	5

2.29.10 SAMPLE COLLECTION OR INSTRUMENT OPERATION

SHUTDOWN PRODCEDURE

It is important that the instrument is in the **READY** Operating Mode when it is turned off. Otherwise, the monitor will enter the Stop Operating Mode the next time the instrument is turned on.

Execute the following steps to turn off the Series 5400 monitor:

1) If the instrument is currently in the READY Operating Mode, skip to step 2. Otherwise, press **RUN/STOP** while in the RUN Operating Mode. In response to this command, the soft key functions change to three stop options. Choose the **EndCyc** option. This option will finish the current cycle being executed and enter the READY Operating Mode when it is finished. The operating mode displayed in the upper right hand corner of the Main Screen is RUN-C, indicating that the unit will stop operating at the end of the current instrument cycle.

2) Power down the instrument by pressing the power switch on the front face of the instrument.

3) Turn off the sample pump by unplugging it.

2.29.11 HANDLING AND PRESERVATION OF SAMPLES

Not applicable.

2.29.12 SAMPLE PREPARATION

Not applicable.

2.29.13 PREVENTIVE MAINTENANCE AND REPAIRS

Perform the maintenance procedures listed in **Table 13-1** at the frequency noted in the table.

Table 13 - 1 Maintenance procedures for the R&P 5400 OC/EC instrument.

Task	Maintenance Procedure	Frequency	Operating Manual Section
1.	Clean R&P PM-2.5 inlet	1-3 month	App. F.1
2.	Clean front intake filters	3 months	12.4.1
3.	Test batteries-exchange if necessary	6 months (replace as needed)	12.4.2
4.	Exchange internal large in-line filter	6 months or as needed	12.4.3
5.	Exchange external large in-line filter	6 months or as needed	12.4.4
6.	Exchange collectors A and B	6 months or as needed	12.4.7
7.	Rebuild sample pump	18 months	Refer to rebuild kit
8.	Exchange furnace burners	3 months or as needed	12.4.5
9.	Exchange afterburner burners	3 months or as needed	12.4.6
10.	Exchange fuses	As needed	3.25 (Service Manual)

2.29.14 TROUBLESHOOTING

The R&P 5400 OC/EC instrument will report status codes with each measurement cycle. A status code of “OK” reports that the instrument has not failed any of its internal tests. When the code is not “OK”, then the red light on the front of the instrument will also be lit. In the event of a non-critical error, the status light is turned on continuously. If a critical trumpet valve failure (VA or VB) occurs, the status light blinks to attract the user’s attention. The status codes can be accessed in the following manners:

- During the current measurement cycle, the status code will be displayed in the top left-hand corner of the instrument screen. An explanation of the status code can be displayed by depressing the **F1:StCode** button.

- The status codes from prior measurements are shown by first depressing the **F4:Data** button and progressing through the data archive by pressing **F1: -cycle** or **F2: +cycle.** The status code is displayed in the bottom left-hand corner of the instrument screen. An explanation of the status code can be displayed by depressing the **F3:Status** button.

The R&P 5400 Service Manual has detailed troubleshooting guides. If a status code is displayed on the current measurement cycle or in prior measurement cycles, consult **Table 14-1** to determine which troubleshooting guide should be followed.

All troubleshooting should be noted in the instrument logbook, including the time the instrument was taken offline and placed back online, the type of maintenance or troubleshooting that was performed on the instrument, and the audit results that verified the instrument error was fixed.

Table 14- 1 Troubleshooting guidance for the R&P 5400 OC/EC instrument.

Status Code	Error Type	Service Manual Section
OK	No errors	N/A
FA/FB	Filter Temperature error	2.2
AA/AB	Afterburner Temperature error	2.2
VA/VB	Trumpet Valve Movement error	2.2
E	External Sample Tube error	2.2
LA/LB	Analysis Loop Leak	2.2
C	Audit Failure	2.2
Y	Power Reset	2.2
Z	Power Failure	2.2
M	Flash Memory error	2.2
S	Serial Port error	2.2
X	AC Voltage Out of Bounds	2.2
H	CO_2 Meter Out of Range – High	2.2
L	CO_2 Meter Out of Range – Low	2.2
W	Sampled Volume Out of Bounds	2.2

2.29.15 DATA ACQUISTION, CALCULATIONS AND DATA REDUCTION

Not applicable.

2.29.16 COMPUTER HARDWARE AND SOFTWARE

The R&P5400 allows the user to monitor the state of the instrument in great detail. There are several different screens that can be accessed to observe various operating parameters starting with the overall state of the instrument to the states of the individual components. The instrument software is described in more detail in Section 3 of the instrument manual.

The operating mode of the Series 5400 is displayed in the upper right hand corner of the Main Menu screen. The different operating modes are described in Section 5 of the Series 5400 manual.

The Operating Statistic Screen displays additional operating information about the Series 5400 monitor. From the Main Screen, press **F2:Stats** and then **F2:OpStats** to enter this screen. The information displayed on the Operating Statistics Screen is described in Section 6of the Series 5400 manual.

The instrument cycle of the Series 5400 contains over 20 individual steps. The current states of collectors A and B are displayed in the Filter Statistics Screen. The Filter Statistics Screen can be viewed by pressing the softkey **F2:Stats** when in the main screen, followed by **F2:OpStats** and **F2:FltStat**. Each of the individual steps is described in Section 3 of the Series 5400 manual. This screen also displays several other values pertinent to the sample collection and analysis. Each of the displayed variables is defined in Section 6 of the Series 5400 manual.

2.29.17 DATA MANAGEMENT AND RECORDS MANAGEMENT

Refer to Speciation Trends Network Data Management Plan.

2.29.18 APPENDIX A: DATA DOWNLOADING COLUMN HEADERS

1.1.1.1.1.1.1.1 Carbon Concentration Data
Cycle Number
Start Time (hh:mm:ss)
Start Date (dd-mmm-yy)
Filter ID (0:filter A, 1:filter B)
Collection Time (sec)
Avg Collection Flow Rate (l/min)
Collection Volume (L)
Collection Temp set point (°C)
Purge CO2 Concentration (ppm)
Status Code (PRC 6)
MC1 (ug/m3)
MC2 (ug/m3)
MC3 (ug/m3)
MCF (ug/m3)
MC1' (residual, ug/m3)
MC2' (residual, ug/m3)
MC3' (residual, ug/m3)
MCF' (residual, ug/m3)
M0 (raw, ul)
M1 (raw, ul)
M2 (raw, ul)
M3 (raw, ul)
MF (raw, ul)
M0' (residual, ul)
M1' (residual, ul)
M2' (residual, ul)
M3' (residual, ul)
MF' (residual, ul)
Offset1 (ug/m3)
Offset2 (ug/m3)
Offset3 (ug/m3)
OffsetF (ug/m3)
Software Version

1.1.1.1.1.1.1.2 Format of Set Point Data Records
Cycle Number
Start Time (hh:mm:ss)
Start Date (dd-mmm-yy)
External Sample Tube Temp Set Point (°C)
Afterburner Temp Set Point (°C)
Plateau 1 Temp Set Point (°C)
Plateau 2 Temp Set Point (°C)
Plateau 3 Temp Set Point (°C)
Plateau F Temp Set Point (°C)
Plateau 1 dwell set point (sec)
Plateau 2 dwell set point (sec)
Plateau 3 dwell set point (sec)
Plateau F dwell set point (sec)
Filter ID (0: filter A, 1:filter B)
Collection Time (sec)
Avg Collection Flow Rate (l/min)

Collection Volume (L)
Collection Temp Set Point (°C)
Purge CO2 concentration (ppm)
Status Code
MC1 (ug/m3)
MC2 (ug/m3)
MC3 (ug/m3)
MCF (ug/m3)
MC1' (residual, ug/m3)
MC2' (residual, ug/m3)
MC3' (residual, ug/m3)
MCF' (residual, ug/m3)
M0 (raw, ul)
M1 (raw, ul)
M2 (raw, ul)
M3 (raw, ul)
MF (raw, ul)
M0' (residual, ug/m3)
M1' (residual, ug/m3)
M2' (residual, ug/m3)
M3' (residual, ug/m3)
MF' (residual, ug/m3)
Offset1 (ug/m3)
Offset2 (ug/m3)
Offset3 (ug/m3)
OffsetF (ug/m3)
Sofware Version

1.1.1.1.1.1.1.3 Calibration/Audit Data Records
Start Time (hh:mm:ss)
Date (dd-mmm-yy)
Const1 (ul)
Const2 (ul)
Const3 (ul)
Manual (1) or Automatic (0)
Calibration (1) or Audit (0)
Pass (1) or Fail (0)
Leak pass (1) or Fail (0)

2.29.19 APPENDIX B: WEEKLY SITE VISIT QA CHECKS

1) **Last Audit Results**: From the Main Screen press "**Data**", "**More**", "**AudtDat**" to view the most recent audit results. Enter the data onto the form.
2) **5400 Status**: From the Main Screen press "**Data**", "**-Cycle**", and note the collector (A or B – in the upper right hand corner of the Data Screen) and the status code (found in the lower left hand corner of the Data Screen) on the form. Press "**-Cycle**" again to view the other collector and note the data on the form.
3) **Filter Count**: From the Main Screen press "**Stats**" and not Filter Count A and Filter Count B on the form.
4) **Flow A & B**: From the Main Screen press "**Data**", "**-Cycle**" and note the flow from the most recent completed analysis and its collector (A or B) on the form. Press **"-Cycle**" again and note the flow from the other collector on the form.
5) **LiCor Calibration: To Be Completed if Audit Data indicate CO2 zero outside 0 +/- 5 ppm or if Audit Span result outside +/- 10% of target value.**

   5.1. Push **Run/Stop**

   5.2. Push **F2: EndCyc**

   5.3. Select "**Immed**". Wait for all temperatures to cool to < 75C.

   5.4. Press "**Menu**" and "**Service Mode**" and enter Service Mode.

   5.5. Open the 5400, disconnect the inlet and pull out the bulkhead.

   5.6. Disconnect the rainbow colored ribbon cable from the RS-232 port under the LiCor sensor and connect the LiCor calibration cable to the port.

   5.7. On the PC start the LI820 software. Click at "file", click "connect" and select appropriate COM port (COM 8 here). It should communicate with the LiCor sensor and read the current CO2 concentration and pressure conditions.

   5.8. From the 5400 Service Menu select "**Manual Motion Tests**" and press "**MFCPres**". Move the cursor to "Circ Pump" with the arrow keys and press "**On/Off**". **CircPump:OFF** should change to **CircPump:ON**.

   5.9. From the 5400 Service Menu select "**Manual Motion Tests**" and press "**Valves**".

   5.10. Move the cursor to "**Purge**" and press the "**On/Off**" key. **Purge:Off** should change to **Purge:On**.

   5.11. Move the cursor to the **N2:OFF** selection with the arrow keys and press "**On/Off**" – **N2:OFF** should change to **N2:ON**. CO2 Free Air is now flowing – allow the system to purge for 2-3 minutes – until the CO2 reading is stable.

   5.12. After the CO2 reading on the Li820 screen has stabilized record the value as the "As Found" value for the zero on the form. Press the "**On/Off**" key on the Manual Motion Test screen to turn return **N2:ON** to **N2:OFF**.

   5.13. Move the cursor to the **CO2Low:OFF** selection with the arrow keys and press "**On/Off**" – **CO2Low:OFF** should change to **CO2Low:ON**. CO2 Low gas is now flowing – allow the system to purge for 2-3 minutes – until the CO2 reading is stable.

5.14. After the CO2 reading on the Li820 screen has stabilized record the value as the "As Found" value for the CO2 Low on the form. Press the "**On/Off**" key on the Manual Motion Test screen to turn return **CO2Low:ON** to **CO2Low:Off**.

5.15. Move the cursor to the **CO2High:OFF** selection with the arrow keys and press "**On/Off**" – **CO2 High:OFF** should change to **CO2 High:ON**. CO2 High gas is now flowing – allow the system to purge for 2-3 minutes – until the CO2 reading is stable.

5.16. After the CO2 reading on the Li820 screen has stabilized record the value as the "As Found" value for the CO2 High on the form. Press the "**On/Off**" key on the Manual Motion Test screen to turn return **CO2 High:ON** to **CO2High: OFF**.

5.17. Repeat steps 1.9, 1.10, and 1.11. When the CO2 value has stabilized in the Li820 Program select "**View**" and the "**Calibration**" from the menu. When the calibration window opens click the "**Zero**" button and wait for the LI820 program to reset the zero. When it has finished record the new zero value as the "As Left" value for the CO2 Free Air on the form. Change **NO2** back to **OFF**.

5.18. Repeat steps 1.13. When the CO2 value has stabilized in the Li820 Program record the value as the "As Left" value for the CO2 Low on the form.

5.19. Repeat steps 1.15. When the CO2 value has stabilized in the Li820 Program select "**View**" and the "**Calibration**" from the menu. When the calibration window enter the CO2 High cylinder value (in ppm) into the blank provided in the Li820 calibration window, click the "**Span**" button and wait for the LI820 program to reset the span. When it has finished record the new span value as the "As Left" value for the CO2 High on the form.

5.20. Remove the Licor calibration RS-232 cable from the 5400 and reattach the rainbow colored RS-232 connector to the Licor port. Push the 5400 bulkhead back into the instrument, reattach the sampling line and close the 5400 door.

5.21. From the 5400 Service Menu select "Manual Motion Tests" and press "**MFCPres**". Move the cursor to "**Circ Pump**" with the arrow keys and press "**On/Off**". **CircPump:ON** should change to **CircPump:OFF**.

5.22. From the 5400 Service Menu select "**Manual Motion Tests**" and press "**Valves**".

5.23. Move the cursor to "**Purge**" and press the "**On/Off**" key. **Purge:ON** should change to **Purge:OFF**

5.24. Press "**Escape**" to exit the "**Valves**" screen in the Manual Motion Tests menu and then select "**Exit Service Mode**".

5.25. Tank conc: values on tags attached to cylinders by the wall.

6) Flow Check:

6.1. Remove the PM 2.5 Sharp Cut Cyclone and the PM 10 head from the flow tube on the roof of the shelter. Attach the flow audit adapter to the flow tube with the butterfly valve open.

6.2. Record front panel flow readout and the average of 3 10-point Bios DryCal measured flow averages onto the log sheet.

6.3. If BIOS measured flow differs from front panel readout by more than +/- 5% adjust the flow meter calibration per R&P Service Manual Section 3.5.

7) External Leak Check:

7.1. Push Run/Stop if not already in Service Mode

7.2. Push F2: EndCyc and then F1: Immed

7.3. Push Menu and scroll to the Service Mode item and press Enter.

7.4. Scroll to the Calibration/Audit line with the arrow keys.

7.5. Press F4: FlowCal

7.6. From the FlowCal screen read the current flow from the right side of the screen where you see Cur:x.xx and note on your log sheet.

7.7. Press F1: On/Off to turn on instrument flow.

7.8. Read the current flow from the right side of the screen – it should be nominally 16.7 lpm.

7.9. Remove the PM 10 head from the instrument inlet and replace with the butterfly valve flow audit adapter. Close the valve.

7.10. Read the current flow from the FlowCal screen and compare to the initial reading you obtained before turning on the pump in step 3.7.

7.11. If the capped flow exceeds the pump off flow by more than 0.15 lpm there is a leak.

7.12. When finished press F1: On/Off to turn off the flow.

7.13. Remove the flow adapter from the inlet and replace the PM 10 head.

7.14. Press the Escape key to return to the Service Menu.

7.15. If you don't need to run any more procedures select Exit Service Mode to return and press Run/Stop to return to normal operations.

8) Internal Leak Check:

8.1. Push **Run/Stop**

8.2. Push **F2: EndCyc**

8.3. Push **Menu** and go into the **Service Mode**

8.4. Scroll down to **System Maintenance** and press enter.

8.5. Scroll down to **Leak Test** and press enter, then START.

8.6. When finished note the results on the form.

8.7. Press ESC to return to Service Menu.

9) Run Definitions Check:

9.1. From the Main Screen press **F3: RunDef** or push **Menu** and scroll down to Run Definitions and push enter.

9.2. Confirm that all Run Definitions match those on the log sheet.

9.3. Press the **ESC** key to return to the Main Screen.

10) Lamp Status:

10.1. Pull the bulkhead out of the 5400 and remove the shield over the ovens.

10.2. Examine all lamps for clarity and condition. If you see more than slight discoloration of the glass in the lamp or if there is any indication that the glass has become misshapen (bulging) replace the lamp.

10.3. If any lamp is changed run an **Oven Cal** as outlined in lines 10.5 – 10.9 below.

10.4. Enter the results on your log sheet.

10.5. To adjust the lamp intensities you must be in Service Mode:

10.6. Push Menu and go into the service mode.

10.7. Scroll down to **Calibration/Audit** and push **F3:Oven Cal**

10.8. Follow the instructions on the screen. Make sure the lamps are all a strong (but not bright) orange color.

10.9. Make sure you press enter when finished with the adjustments.

11) Cyclone and Inlet cleaning:

11.1. Remove the PM 10 head and the PM 2.5 Sharp Cut Cyclone from the flow tube on the shelter roof.

11.2. Disassemble them both and clean all surfaces with Kimwipes and distilled water.

11.3. Lubricate all o-rings with Krytox grease.

11.4. Reassemble the components and place them back on the flow tube.

2.29.20 APPENDIX C: WEEKLY PROCEDURES LOG SHEET – R&P 5400

Last Audit Results

	Expected Value	Actual Value
Date		
Const 1		
Const 2		
Const 3		
Audit Pass/Fail		
Leak Pass/Fail		

Instrument Status

Status Light	S.B. off
Reset?	Yes/No
Filter Count A	S.B. <2500
Filter Count B	S.B. <2500
Flow A	S.B 15 – 18 lpm
Flow B	S.B 15 – 18 lpm
Instrument mode as left (RUN)	S.B in RUN

Licor Calibration Results (if needed)

	As Found	As Left	Tank Conc.
CO2 Free Air			
CO2 Low			
CO2 High			

Flow Check Results

	Actual (BIOS)	Indicated (R&P Display)
Side A		
Side B		

External Leak Check Results

1) Flow with pump off
2) Flow with pump on
3) Flow with pump on and inlet capped
4) External leak (Flow 3 – Flow 1)

Internal Leak Check Results

	Pass/Fail	Rate

Side A
Side B

Run Definition Check

		OK?			OK?			OK?
Coll. Time	1 Hr		P1	0 C		D1	0 Sec	
Coll. Temp	50 C		P2	0 C		D2	0 Sec	
Aburn Temp	750 C		P3	275 C		D3	480 Sec	
Ext. Temp	0 C		P4	750 C		D4	240 Sec	
Coll. Flow	16.7lpm							

Lamp Status Check

	OK/Replaced?
AfterBurner A	
Oven A1	
Oven A2	
Oven A3	
Oven A4	
AfterBurner B	
Oven B1	
Oven B2	
Oven B3	
Oven B4	

Actions Taken/Notes

2.29.21 APPENDIX D: 5400 MANUAL LEAK CHECK

Equipment needed:

1—1/8” swagelock cap
1—1/4” swagelock cap
1—1/4” to 1/8” swagelock reducer
2—7/16” wrenches
1—9/16” wrench
The LiCor Calibration flow meter

1) Push Run/Stop then push F1 for Immediate (Note: If any of the temperatures on the front of the main screen are above 100 C allow the 5400 to cool before continuing with the next step).
2) Put the 5400 in the Service Mode.

This section will check for a leak in the Pinch Valve and Impactor filter.

1) Push Menu and scroll to Manual Motion Test then push F2 for valves. In the Valves menu make sure Trumpet A is Measure and Trumpet B/ Pinch is Collect (This will check for a leak on Side A). If they are not in this configuration, move the cursor to Trumpet A and push F2 for On/Off then move it to Trumpet B/Pinch and push F2 for On/Off.
2) Push Menu and scroll to Instrument Setup and push Enter. Then push F1 for Configure (This will allow you to see the CO2 Pressure or LiCor Pressure).
3) Pull the bulkhead out on the 5400 and locate the pinch valve, valve manifold and optical bench (Figure 1).
4) Locate the LiCor calibration Flow Meter. Make sure the flow meter is closed or turned completely clockwise.
5) Disconnect the A2 tubing from the valve manifold and connect it directly to the top of the flow meter (Figure 2).
6) Disconnect the A3 tubing from the valve manifold and using a 1/4" swagelock cap and 1/4" to 1/8” swagelock reducer, cap the tubing at A3 (Figure 2).
7) Connect the lower tubing from the flow meter to the CO2 Free Air gas cylinder.
8) While watching the CO2 Pressure the on 5400 monitor, open the flow meter valve. The pressure will start out just below 1000 millibar (mbar). The pressure should increase to approximately 1100 mbar. If the pressure doesn’t rise make sure the flow meter is flowing. After the pressure has increased close the flow meter valve.
9) If the pressure is constant escape to the main menu and change the configuration so that Trumpet A is Collect and Trumpet B/Pinch is Measure as stated in Step 3 (This will check for a leak on Side B).
10) Follow Steps 4 – 10.
11) If the pressure is constant on both, the Pinch Valve, CO2 (LiCor) Sensor and Impactor Filters are leak free. Now check for a leak in the Valve Manifold.
12) If the pressure isn’t constant on Side A but constant on Side B, you have a leak on Side A and it could be in the impactor filter or the pinch valve.

13) If the pressure isn't constant on Side B but constant on Side A, you have a leak on Side B and it could be in the impactor filter or the pinch valve.
14) If the pressure isn't constant on either side then check for a leak in the CO2 (LiCor) Sensor.

FIGURE 1

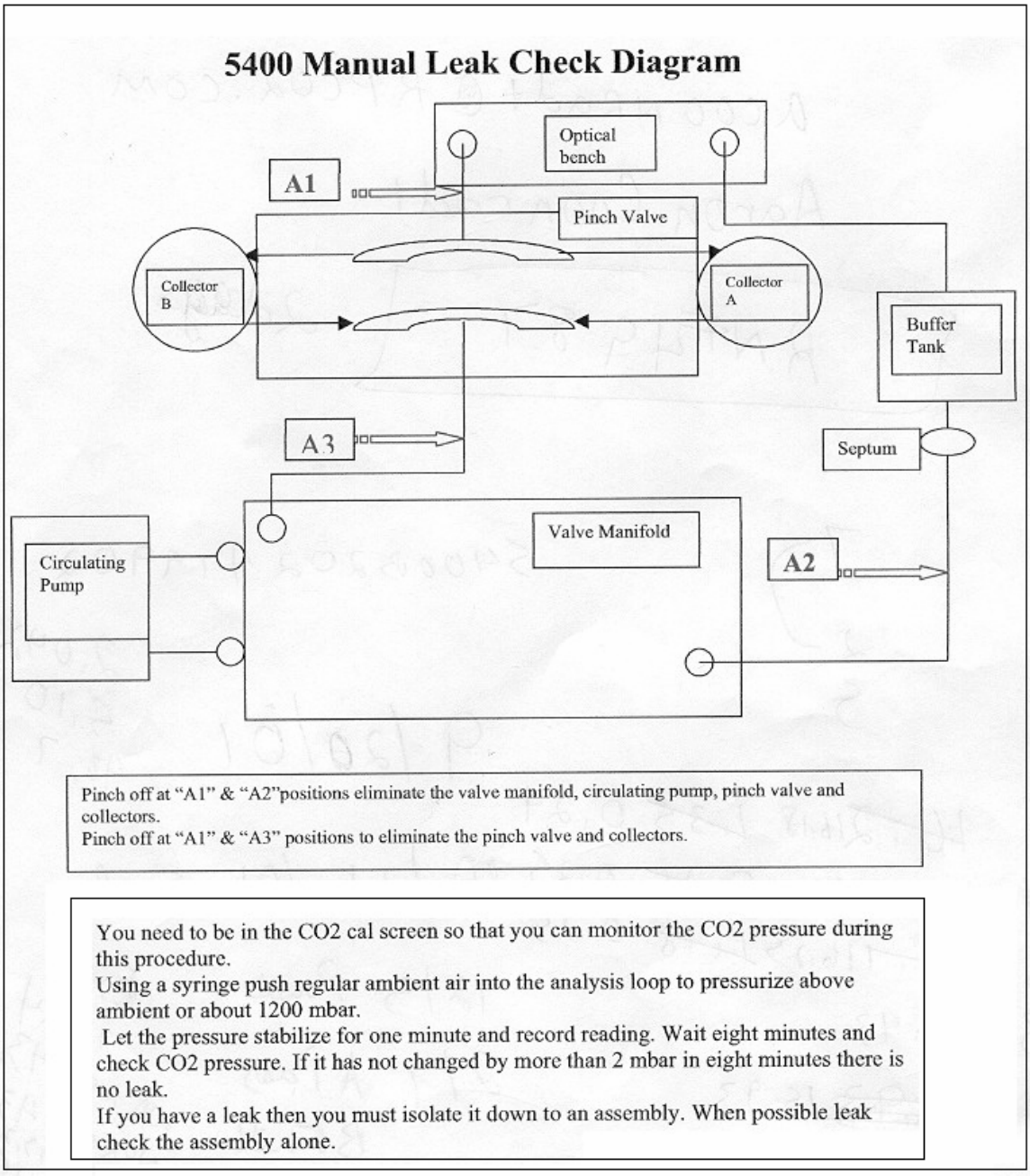
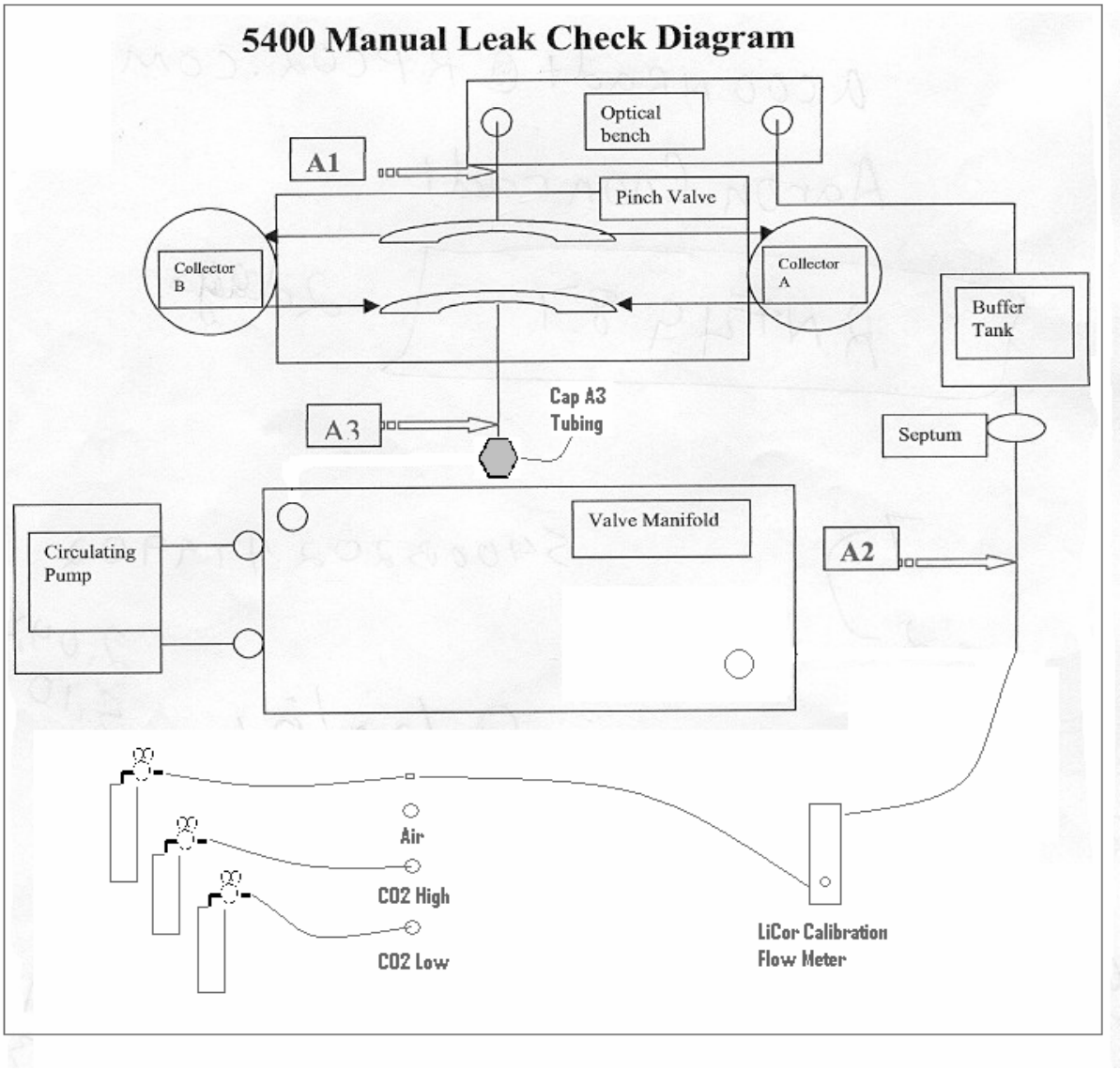


FIGURE 2



This section will check for a leak in the Optical Bench (LiCor).

1) Push Menu and scroll to Instrument Setup and push Enter. Then push F1 for Configure (This will allow you to see the CO2 Pressure or LiCor Pressure).
2) Locate the LiCor calibration Flow Meter. Make sure the flow meter is closed or turned completely clockwise.
3) Disconnect the A2 tubing from the valve manifold and connect it directly to the top of the flow meter (Figure 3).

4) Disconnect the A1 tubing from the Pinch Valve and cap the tubing at A1 using a 1/4" swagelock cap and 1/4" to 1/8" swagelock reducer and the 1/8" swagelock to barbed tubing fitting from A3 (Figure 3).
5) Connect the lower tubing from the flow meter to the CO2 Free Air gas cylinder.
6) While watching the CO2 Pressure on the 5400 monitor, open the flow meter valve. The pressure will start out just below 1000 millibar (mbar). The pressure should increase to approximately 1100 mbar. If the pressure doesn't rise make sure the flow meter is flowing. After the pressure has increased close the flow meter valve.
7) If the pressure is constant the Pinch Valve is leak free.
8) If the pressure isn't constant disconnect the tubing directly above the Buffer Tank and connect the tubing to the flow meter using the 1/8" swagelock to barbed tubing fitting from A2 (Figure 4).
9) Follow steps 5 and 6.
10) If the pressure is constant the Buffer Tank or Septum is your leak location.
11) If the pressure isn't constant the leak is in the Optical Bench (LiCor).

FIGURE 3

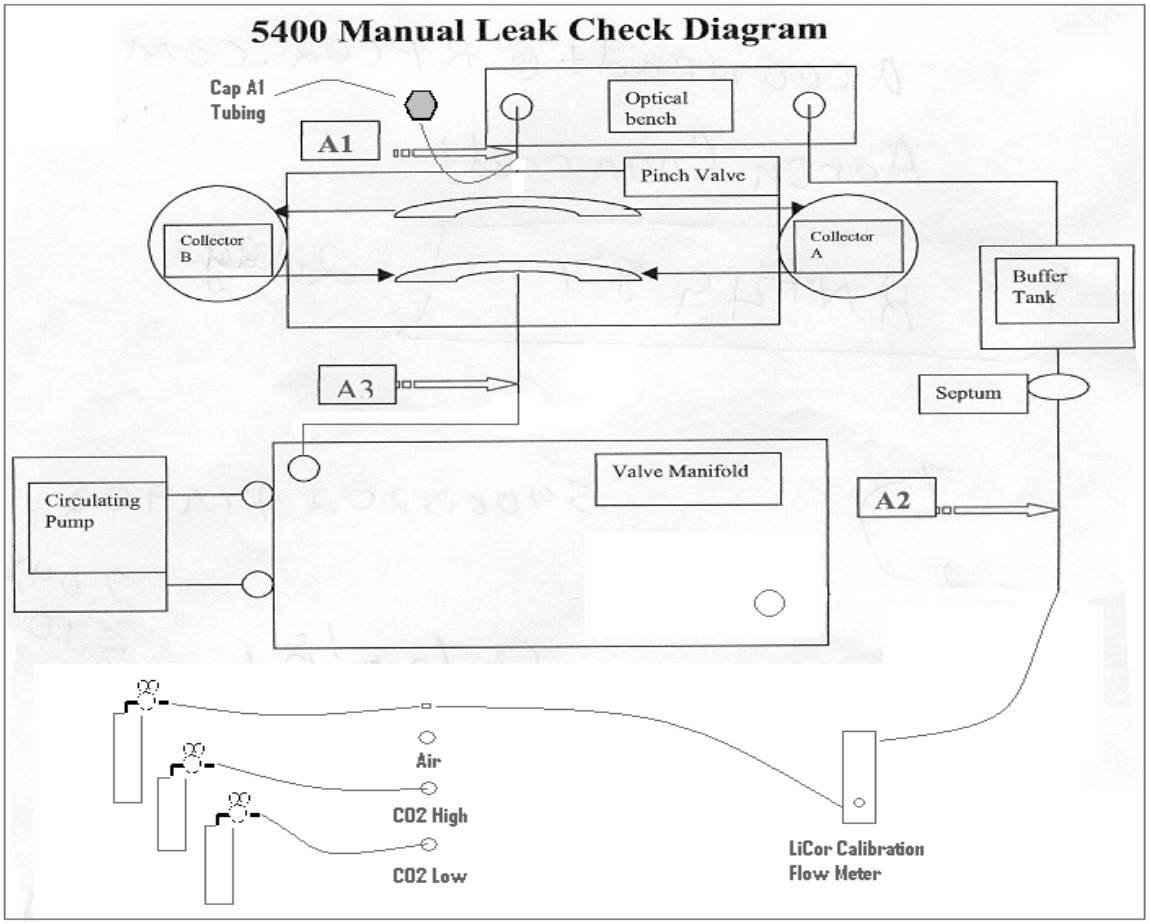
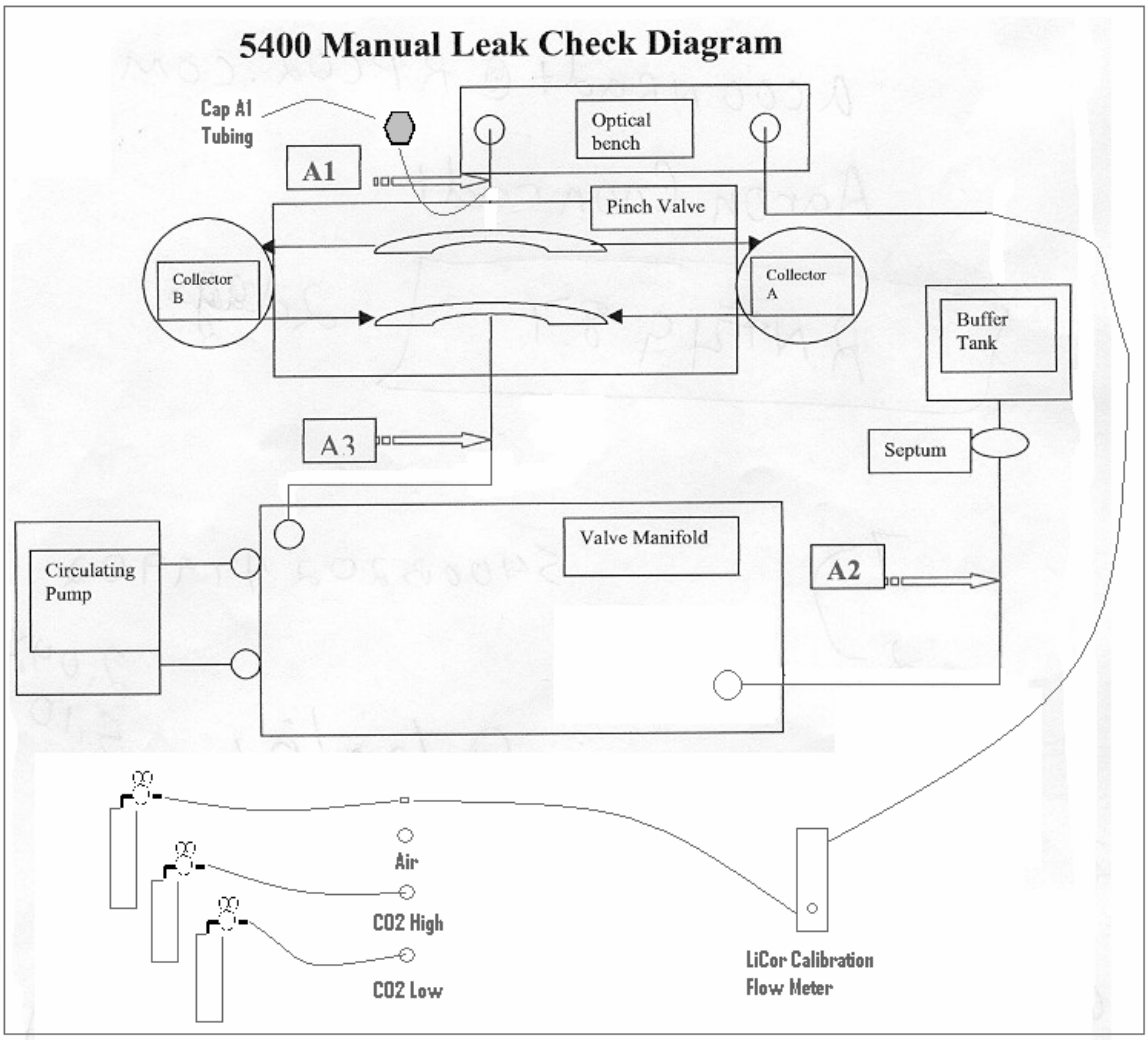


FIGURE 4

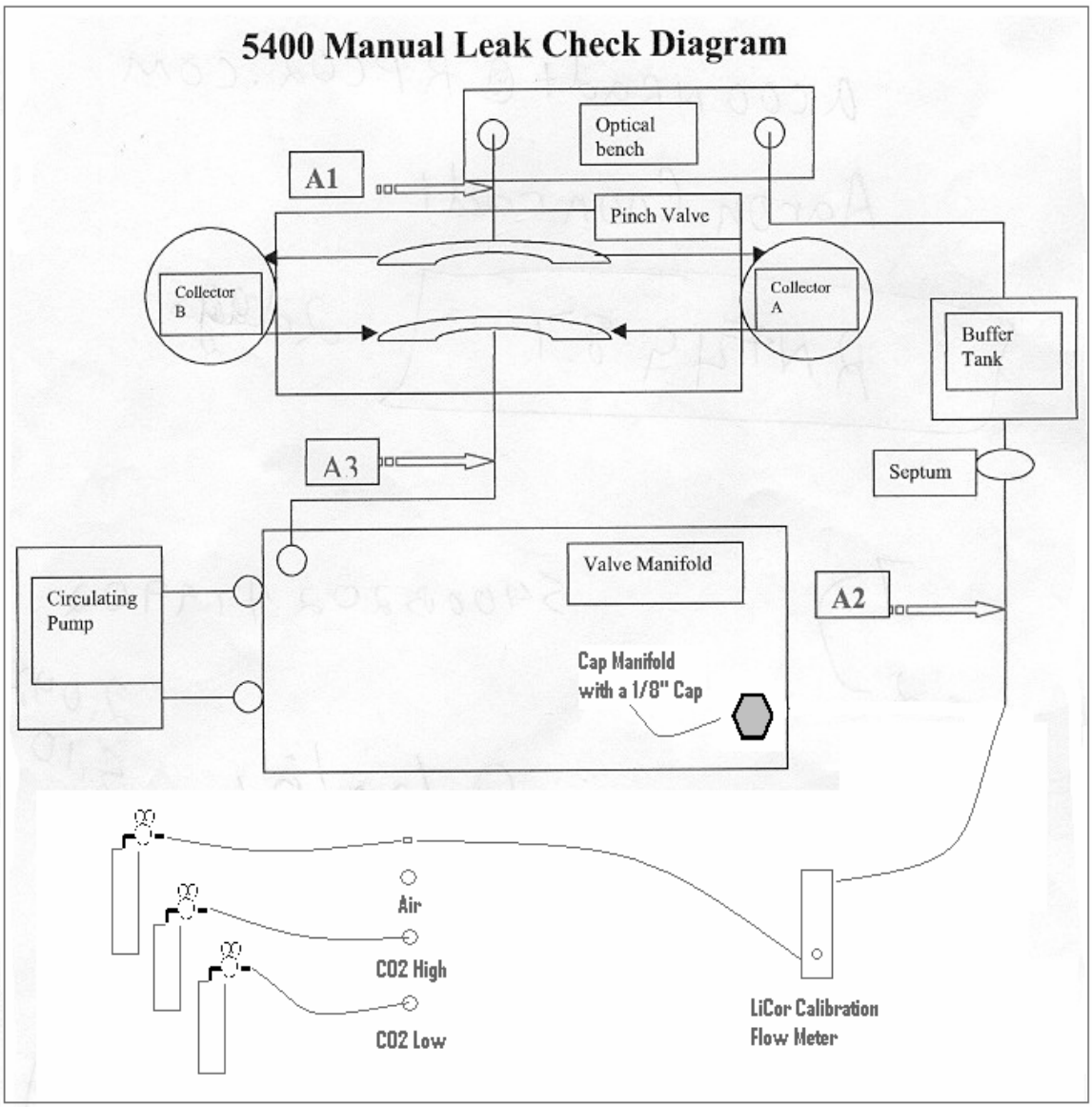


This section will check for a leak in the Valve Manifold.

1) Push Menu and scroll to Manual Motion Test then push F2 for valves. In the Valves menu make sure Trumpet A is Measure and Trumpet B/ Pinch is Collect (This will check for a leak on Side A). If they are not in this configuration, move the cursor to Trumpet A and push F2 for On/Off then move it to Trumpet B/Pinch and push F2 for On/Off.
2) Push Menu and scroll to Instrument Setup and push Enter. Then push F1 for Configure (This will allow you to see the CO2 Pressure or LiCor Pressure).
3) Pull the bulkhead out on the 5400 and locate the pinch valve, valve manifold and optical bench (Figure 5).
4) Locate the LiCor calibration Flow Meter. Make sure the flow meter is closed or turned completely clockwise.

5) Disconnect the A2 tubing from the valve manifold and connect it directly to the top of the flow meter (Figure 5).
6) Using a 1/8" cap close the manifold (Figure 5).
7) Connect the lower tubing from the flow meter to the CO2 Free Air gas cylinder.
8) While watching the CO2 Pressure the on 5400 monitor, open the flow meter valve. The pressure will start out just below 1000 millibar (mbar). The pressure should increase to approximately 1100 mbar. If the pressure doesn't rise make sure the flow meter is flowing. After the pressure has increased close the flow meter valve.
9) If the pressure is constant the manifold is leak tight.
10) If the pressure isn't constant clean the purge solenoid and try again.
11) If the pressure still isn't constant clean all solenoids and try again.
12) If the pressure still isn't constant call Plano for Technical Assistance.

FIGURE 5


5400 Manual Leak Check Diagram
Optical bench
A1
Pinch Valve
Collector B
Collector A
Buffer Tank
A3
Septum
Valve Manifold
Circulating Pump
A2
Cap Manifold with a 1/8" Cap
Air
CO2 High
CO2 Low
LiCor Calibration Flow Meter

2.29.22 APPENDIX E: COMMONLY USED PROCEDURES FROM SEARCH NETWORK 5400 OPERATIONS

Table of Contents

1) SOFTWARE UPGRADE

1.1. Before you start, Download the Set Points file and the Audit file

1.2. Push **Run/Stop**

1.3. Push **F2:EndCyc**

1.4. Push **F5:Setup**

1.5. Push **F1:Output**

1.6. Push **F2:RS-232**

1.7. Go to protocol & push **EDIT**.

1.8. Using the F1 "-List" & F2 "+List" scroll until you find "NONE" & push "enter".

1.9. Go back to main screen

1.10. Make sure you have the RS-232 cable connected from your computer to the 5400

1.11. If are using a floppy put it in.

1.12. Go to the Start menu and then to "Run"

1.13. In the location "Open:" type in " A:\RPLOAD 5400.BIN " and press OK

1.14. The program should come up on your computer and say, "waiting to reset" then it will load.

1.15. When the program has loaded the main screen will come back up on the 5400.

1.16. Disconnect the RS-232 cable

1.17. After it has loaded you may have to reset the 5400. You will know this if you go into the Run Definitions screen and you cannot edit anything. If you do not have to reset then continue.

1.18. Change the Protocol back to **AK**

1.19. Check Run Definitions

1.20. Check the A/O under Setup>Output

1.21. Under Setup make sure that "Smoothing" is **off** and the audit frequency is set for **71** cycles.

1.22. Check the Oven Calibration

1.23. Do a leak check

1.24. Under CO2 cal check the Low% (~350ppm or 0.0350%) and the High% (~1800ppm or 0.1800%). The low% and high% should match the tank concentrations on site.

1.25. In the CO2 Calibration Screen make sure the LiCor is set to LiCorCom

1.26. Do a LiCor cal

1.27. Do an **F3:Audit**

1.28. If all is OK then put the machine back into Run Mode

2) SYSTEM RESET

2.1. Always download data prior to a reset.

2.2. Turn off power on the bottom right corner of the instrument.

2.3. When you turn the power back on the second screen that comes up push **F5:Reset**.

2.4. The system will reset (understand that when the system resets everything is erased).

2.5. After the main screen appears you will need to check the machine as follows.

2.6. Do an oven calibration

2.7. Check the Run Definitions

2.8. Check the Setup--Audit frequency (**71**), Smoothing (**NO**), A/O, and RS-232 (**AK** Protocol)

2.9. Go into the service menu under system maintenance and do a New Filter A, New Filter B and Leak Test.

2.10. Under Calibration/Audit make sure the LiCor is set to LiCorCom

2.11. On the CO2 Calibration screen check the CO2 Low % and CO2 High %. Make sure they match the cylinder concentrations.

2.12. Do a LiCor calibration and then a **F3:Audit**.

2.13. When all is finished put the machine into the Run mode.

3) RUN DEFINITIONS

3.1 Push **Run/Stop**

3.2. Push **F2:EndCyc**

3.3. Push **F3:Run Def** or push Menu and scroll down to Run Definitions and push enter.

3.4. Use the edit button and input the correct settings

3.5. Settings:

3.6. Collection Time:	1hr		Analysis Type: Reg		
3.7. Col Temp:	0.0 C	P1:	0.0 C	D1:	0.0 sec
3.8. Aburn Temp:	750.0 C	P2:	0.0 C	D2:	0.0 sec
3.9. Ext. Temp:	0.0 C	P3:	275 C	D3:	480 sec
3.10.	Col Flow:		16.7	P4: 750 C D4:	240 sec

3.11. Make sure you press enter when finished.

4) A/O SETUP

4.1 You are able to make changes to the A/O while the machine is running

4.2 Push **F1: Output**

4.3 Push **F2: RS-232**

4.4 Push **F1: A/O**

4.5 Input the correct settings:

Parm	Minimum	Rural Max (ug/m3)	Urban Max (ug/m3)
1. MC3	0.0	30.0	50.0
2. MC Final	0.0	30.0	50.0
3. CO2 Purge	0.0	1000	1000
Max Output:	5V	5V	5V

4.6 Make sure you press enter when finished.

5) RS-232 SETUP

5.1. Push **F5: Setup**

5.2. Push **F1: Output**

5.3. Push **F2: RS-232**

5.4. Protocol should be set to **AK**.

6) I/O CALIBRATION

6.1. Push **Run/Stop**

6.2. Push **F2:EndCyc**

6.3. Push **Menu** and go into the service mode.

6.4. Scroll down to **Calibration/Audit**

6.5. Push **F1:I/O Cal**

6.6. For further instruction refer to section 10.1 in the R & P Manual.

7) SYSTEM SETUP

7.1. From the main screen, set up additional operating parameters by pressing the **F5: Setup** soft button. Use the **EDIT** key to make changes. Use the arrow keys to move around the display. Press the **ENTER** key to save the edits.

7.2. Input the following settings

7.3. A/S Temp: 25 25 Audit Freq: 71 cyc

7.4. A/S Pres: 1.00 1.00 Leak Check: 0 cyc

7.5. Smoothing? NO Audit Limit: 10%

7.6. Curr Time: xx:xx:xx

7.7. Curr Date: xx-xx-xx

8) MANUALLY DOWNLOADING FILES

8.1. Make sure the RS-232 cable is connected to the front of the 5400 and to your computer.

8.2. Go to your RP5400 HyperTerminal connection.

8.3. When it opens it should say connected in the bottom left corner.

8.4. On the HyperTerminal go to "Transfer" then scroll down and click on "Capture Text"

8.5. When the next screen comes up you need to type in one of the following two file names. If it is a set points file, type in: C:\txtfiles\CTR_RP5400_SETPTS_112100.TXT (CTR

is the site name and the 6 numbers at the end are for the Date – month/day/year). If it is an audit file: C:\txtfiles\CTR_RP5400_AUDIT_112100.TXT Then press OK.

8.6. On the 5400 push **F4:Data**

8.7. Push **F5:More**

8.8. Push **F1:SetPts**

8.9. Use F1 "-List" and F2 "+List" to move to the correct data file (this number displays in the top left corner). Make sure the data file displayed is the last file downloaded minus 5.

8.10. Make sure the screen or file being downloaded is labeled "Set Point Data" or "Audit Data". If not escape back to the main screen and start over.

8.11. Push **F4:Download** twice.

8.12. You will see numbers scroll across the computer screen.

8.13. On the computer go to "Transfer" > "Capture Text" > "Stop"

8.14. The download is now complete.

8.15. For the Audit Data use the same procedure except after you push **F5:More** then push **F3:Audit**. After you are in the Audit Data Screen push page down once.

9) 5400 CO2 AUDIT

9.1. Push **Run/Stop**

Push **F2: EndCyc**

9.2. Push Menu and go into the service mode.

9.3. Scroll down to Calibration/Audit

9.4. Push **F2:CO2 Cal**

9.5. Push **F3:Audit**

9.6. When finished exit the service mode and put the machine back into the Run mode.

10) LICOR CALIBRATION

10.1. Push **Run/Stop**

10.2. Push **F2: EndCyc**

10.3. Open the 5400 and pull out the bulkhead

10.4. Find the 9-pin DB connector or RS-232 port. It is on the left side of the bulkhead at the back. It should be very close to or directly under the pink insulated LiCor sensor and to the right of the glass-mixing chamber. With some versions of the 5400 the RS-232 connector will be located in the middle of the machine above the solenoid manifold.

10.5. Connect your LiCor extension cable to this location then your RS-232 cable that goes to your computer to it.

10.6. With a 7/16" wrench disconnect the 1/8" fitting in the middle on the left side of the trumpet valve. You will have to take the silver shield off to get to the fitting. On some 5400 models skip this step.

10.7. Find your manifold. It has 7 solenoids on it with 3 tubes coming out of the top and one coming out of the bottom. With a 7/16" wrench take the bottom tube off.

10.8. Connect your flow meter to the bottom tube. Leave the other tube open.

10.9. Close the flow on the flow meter.

10.10. Attach the lower side of the flow meter to the CO2 Free Air Cylinder. To do this, detach the gas cylinder line on the rear of the 5400. This is a quick disconnect fitting. There are four fittings to the left rear of the 5400 all as follows:

10.10.1. O- CO2 Purge----AIR

10.10.2. O- CO2 Free Air----N2

10.10.3. O- Span Gas (~2500 ppm)----CO2% High

10.10.4. O- Precision gas (~400 ppm)----CO2% Low

10.11. Once there is gas connected, open the flow meter until the flow is at 1 LPM.

10.12. Let this purge the line for 2 or 3 minutes

10.13. While purging open your Li800 program on the computer (It may be on Com 1 or 2).

10.14. Click the **Configure** button.

10.15. Make sure the enable heater and pressure compensation is **checked** and the filter is set for **20 seconds**. Then click **OK**.

10.16. Click **Quit**.

10.17. After the number on the Li-800 screen has stabilized record this in your site log. This will be a before calibration number for the zero.

10.18. Reconnect your CO2 Free Air to the back of the 5400 and connect your precision gas to the flow meter. Let it stabilize and record this number for the "before calibration" precision reading.

10.19. Reconnect your precision gas to the 5400 and connect your span gas to the flow meter. Let it stabilize and record this number for the "before calibration" span reading.

10.20. Connect the CO2 Free Air cylinder and let it purge the system for 2-3 minutes.

10.21. Click **Calibrate**.

10.22. Click **Zero IRGA**--In the bottom left of the Li-800 program the progress will display.

10.23. When finished attach the span gas and let it purge for 2-3 minutes

10.24. Click **Span IRGA**. A screen will open to ask what the concentration is on the span gas cylinder. Input the concentration from the tag on the gas cylinder.

10.25. When finished click **Quit**. Now the number on the screen should match the ppm of the span gas cylinder within +/- 5 ppm. Repeat steps 8.30 through 8.32 if the screen does not match the span cylinder concentration within +/- 5 ppm. Write this number in your site log as the after calibration span reading.

10.26. Reattach the CO2 precision gas and wait 2-3 minutes for the sensor to stabilize. The sensor reading should match the cylinder concentration within +/- 5ppm. If it doesn't but is within +/- 10 ppm recalibrate. If it is over the 10ppm threshold call Plano. If all is OK, write this number in the site log as the "after calibration" precision reading.

10.27. Reattach the CO2 Free Air. It should drop to zero or below. GIVE IT TIME. It could take a few minutes. If this number is within +/- 3ppm write it down in your site log as the after calibration zero. If it is not within +/- 3ppm recalibrate.

10.28. If all calibrations are good fill out the form below.

10.29. With the calibration finished and all gases reconnected press menu and go into the service mode.

10.30. In the service mode scroll to **System maintenance** and press enter then scroll to **Filter Change/Max Flow Test** and press enter.

10.31. Write the **Filter Count** for both Filter A and B onto the form below.

10.32. Fax the form to Plano and put the 5400 back into run mode.

Before Cal		Cylinder Concentrations	
Zero	_____	Precision	_____
Precision	_____	Span	_____
Span	_____		

After Cal		Filter Count	
Zero	_____	Filter A	_____
Precision	_____	Filter B	_____
Span	_____		

11) CLEANING THE LICOR

11.1 SHUT DOWN THE 5400 AND TURN IT OFF. (YOU MAY EVEN WANT TO UNPLUG THE 5400 BUT IT IS NOT NECESSARY)

11.2. Pull out the bulkhead so that you can reach the LiCor sensor. It is on the top, left, rear of the bulkhead.

11.3. As you pull everything apart make sure you remember how it goes together.

11.4. Unclamp and pull off both pieces of tubing attached to the LiCor.

11.5. Unscrew the LiCor housing.

11.6. Disconnect the ribbon cable on each end of the sensor. Pay careful attention to where the cables were disconnected.

11.7. Take the sensor out of the foam casing. (Make sure you remember which housing is on the right and which is on the left.)

11.8. Remove the four corner screws on the end of the two housings.

11.9. Now that you have the bench or tube separated from the housing be careful not to lose or damage the O-rings.

11.10. You will have two sizes of special swabs in the LiCor kit. Take the larger of the two (Optical Path Swab) and clean the bench with isopropyl alcohol (rubbing alcohol).

11.11. Wet the smaller swab (Reflector Swab) with isopropyl alcohol and clean the concave housing. (Chad: What's the concave housing?)

11.12. Let everything have a chance to dry.

11.13. Before continuing check the bench for haze. If haze is apparent, clean again.

11.14. Reassemble, making sure the O-rings are clean and in place on both ends of the bench.

11.15. Put the foam, ribbon cables, and tubing back on and screw the completed piece back onto the 5400.

11.16. Turn the 5400 back on and do a complete LiCor Calibration.

11.17. Put the 5400 into Run mode.

12) OVEN CALIBRATION

12.1. Push Menu and go into the service mode.

12.1.1. Scroll down to **Calibration/Audit** and push **F3:Oven Cal**

12.1.2. Follow the instructions on the screen.

12.1.3. Make sure you press enter when finished with the adjustments.

12.1.4. Go back to Run mode.

13) FLOW CALIBRATION

13.1 Push **Menu** and go into the **Service Mode**.

13.2 Scroll down to **Calibration/Audit** and push **F4:Flow Cal**

13.3 Take the black flow check adapter and put it on the 5400 inlet.

13.4 Shut it off.

13.5 Push **F1:On/Off**

13.6 After the current flow has stabilized, edit the actual flow and type in 0.0 and press enter.

13.7 After this put your BIOS on the inlet and slowly open the valve.

13.8 Take three stable 10-point averages then adjust the final average to STP.

13.9 Put this number in the space for the actual and press enter.

13.10 If the machine does not work properly or the calibration numbers will not take, do a **Mass Flow Meter Calibration**. This procedure is in the 5400 manual, Section 10.5 - Page 10-10.

13.11 If all is well put everything back into its original configuration and press **Run/Stop**.

14) ZERO CHECK

14.1 When running this check you need to make sure you start at the top of the hour.

14.2 Install a blue Balston filter on the inlet using tubing and the flow check adapter.

14.3 Let the machine run for at least two full hours.

14.4 Take the filter and flow adapter off.

14.5 Write in the site log the day and time (down to the minute) off of the 5400 and from the DAS.

15) INTERNAL LEAK TEST

15.1 Push **Run/Stop**

15.2 Push **F2: EndCyc**

15.3 Push **Menu** and go into the **Service Mode**

15.4 Scroll down to **System Maintenance** and press enter.

15.5 Scroll down to **Leak Test** and press enter.

15.6 When finished write down the results in your site log. Proceed to Section 13 if the leak test does not pass on both collectors.

15.7 Press “ESC” to return to service menu.

16) LEAK TEST TROUBLESHOOTING

16.1 If the leak test will not pass the first time try it again before you make any changes.

16.2 If it still doesn't pass and the leak is small (Leak of 2.5 to 2.8 mbar) then clean the purge solenoid.

16.3 If it doesn't pass and you have a **Gross Leak** then you will need to inspect the impactor filters. If they are damaged, replace. Take particular note of the inner coils around the afterburner lamp. This is a common failure point for collectors.

16.4 If it still doesn't pass call Plano for Technical Support.

17) CO2 PURGE SOLENOID CLEANING

17.1 Shut the machine down but do not turn it off.

17.2 Turn off the vacuum pump.

17.3 Pull out the bulkhead

17.4 Find the valve manifold. It is on the left side of the bulkhead in the middle. It has even solenoids on it with three tubes coming from the top and one from the bottom.

17.5 The purge solenoid is on the top right of the solenoid manifold and says, "Purge".

17.6 Remove the top right and bottom left corner screws.

17.7 When these are removed you should be able to remove the solenoid. (DO NOT try and disconnect the wiring.) Make sure not to lose the two O-rings between the manifold and the solenoid.

17.8 Take the other two screws off of the solenoid.

17.9 When pulling the gold base away from the black piece (the solenoid), **be very careful not to lose the slide or the spring behind it.**

17.10 Clean all pieces with isopropyl alcohol (rubbing alcohol). Make sure you take out the Allen screw and clean it.

17.11 When finished reassemble.

17.12 Turn on the vacuum pump.

17.13 Do a leak test.

17.14 Put the 5400 back into Run mode.

18) COLLECTOR (IMPACTOR) CHANGE OUT

18.1. Shut the machine down.

18.2. Push Menu and go into the service mode.

18.3. Scroll down to "System Maintenance" and press enter.

18.4. Scroll down to "Filter Change" and press enter.

18.5. Write down the filter count for A and B. Then write it on each collector after they have been removed.

18.6. Turn off the main power and unplug the 5400.

18.7. Pull out the bulkhead and locate the collectors.

18.8. Take the cage off that surrounds the collectors.

18.9. Using the orange lamp exchange tool (Orange tubing) and take out the lamp on Afterburner A & B.

18.10. Take off each of the oven covers.

18.11. Disconnect the all of the thermocouples. (The yellow plugs at the front.)

18.12. Using a 1/2" wrench take each filter assembly off. Make sure you label each one. The filter in front is side A and the filter behind is side B.

18.13. Install the new filters exactly how you took the old filter off. After you install the lamp for each afterburner move the socket for the lamp until the lamp is centered in the afterburner. If you cannot get it completely centered make sure it is closer to the thermocouple side. Use the old afterburner thermocouples on the new filter assemblies. When inserting the thermocouples use some of the NO2 heat sink compound around the thermocouple end.

18.14. After everything is back together plug the machine back in and turn it on.

18.15. Push Menu and go into the service mode.

18.16. Scroll down to "System Maintenance" and press enter.

18.17. Scroll down to "Filter Change" and press enter.

18.18. Push New Filter A

18.19. Push New Filter B

18.20. Do a Leak Test

18.21. Put the machine in Run mode.

18.22. Write everything down in the site log then Mark each of the old filters. Make sure you label as follows:

Site ID:

5400 Serial #:

Filter Count:

Date/Time:

19) REPLACEMENT OF AFTERBURNER LAMP

19.1. Power down the 5400 and unplug from the wall.

19.2. Pull out the bulkhead and remove the collector cage.

19.3. Using the orange lamp exchange tool remove the afterburner lamp that needs to be replaced.

19.4. Make sure not to touch the glass part of the new lamp with your hand or skin.

19.5. Install a new lamp.

19.6. Use the 4 adjustment screws on the afterburner lamp base to **precisely** align the lamp in the **exact center** of the afterburner coil of the collector!

19.7. Turn on the 5400 and put into RUN mode.

20) FLOW SENSOR CHANGE OUT

20.1. Put the machine in stop mode.

20.2. Turn off the vacuum pump.

20.3. Pull out the bulkhead.

20.4. On the right side at the rear locate the flow sensor.

20.5. Take the electrical connector loose.

20.6. Disconnect the Swagelok fitting on the end of the large blue main vacuum filter.

20.7. Unscrew the large blue filter from its mounting block.

20.8. Unscrew the flow sensor and main filter mounting screws.

20.9. Unscrew the flow sensor from its mounting block and from the filter-mounting block.

20.10. Put the new sensor on as you took to old sensor off. Make sure you use new Teflon tape.

20.11. When the system is reassembled perform a flow calibration.

20.12. If the flow calibration is good put the machine back into run mode, making sure the vacuum pump is on.

21) BATTERY BACKUP REPLACEMENT & CHECK

21.1. Open the 5400 and at the front left you will see 3 "AA" batteries.

21.2. Looking at the bottom right of the electronics board below the backup batteries you should see two prongs or stems. One is Red (labeled BATV) and the other is Black (labeled DGND).

21.3. Using a voltmeter check across the two stems.

21.4. If the voltage is less than 4.25 Volts, change out the batteries.

21.5. Make sure you put the batteries in the same way you took them out.

22) CO2 PURGE FILTER REPLACEMENT

22.1. The purge filter is the large blue Balston filter on the left rear of the machine.

22.2. Using the quick disconnects take the filter off of the 5400 and disconnect the green tubing.

22.3. Put the fittings from the old filter onto a new filter and reinstall it on the 5400. Make sure you use new Teflon tape.

23) MAIN VACUUM PUMP REPLACEMENT

23.1. Shut the machine down.

23.2. Turn off the vacuum pump.

23.3. Pull out the bulkhead.

23.4. On the right side at the rear you will find a large blue balston filter.

23.5. Disconnect the Swagelok fitting and unscrew the filter from its mounting base.

23.6. Take the old Swagelok fitting and old mounting base and put it on the new filter. Use new Teflon tape on the threads.

23.7. Install the same way you took it off.

23.8. Turn on your vacuum pump.

23.9. Put the machine back into Run mode.