Possum1 User Guide

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Contents

1 Features

The Possum is a versatile portable sampling system for measuring combustion emissions from a wide variety of combustion sources. The Possum system includes a sensor box, sampling probes, accessories, and carrying cases. The system is appropriate for virtually any fuel type including solid fuels such as biomass and coal, liquid fuels such as diesel and oil, and gas fuels such as biogas and propane. The Possum system is appropriate for measuring both large and small combustion sources with and without exhaust stacks, including brick kilns, biochar kilns, burn piles, boilers, furnaces, heating stoves, cooking stoves, and vehicles.

The Possum system has an undiluted sample train for direct measurement of emissions from stacks and chimneys, as well as a dilution system that conditions the emission sample for the diluted sample train to achieve a representative sample of condensible particulate matter and other semi-volatile emissions.

The following parameters in Table 1 are logged to an on-board storage disk at a 1 second time base. The data can be viewed and plotted in real-time using the provided computer and software. The on-board battery provides power for 14 hours of run time.

Table 1: Parameters measured and recorded by the Possum1 sensor box

Parameter	**Range**	**Measurement Method**
CO	0-5000 ppm	electrochemical
CO background	0-5000 ppm	electrochemical
CO high range	0-20000 ppm	electrochemical
CO_2	0 - 50000 ppm	NDIR
CO_2 background	0 - 50000 ppm	NDIR
CO_2 high range	0 - 20 %	NDIR
SO_2	0-2000 ppm	electrochemical
NO	0-250 ppm	electrochemical
NO_2	0-20 ppm	electrochemical
H_2S	0 - 100	electrochemical
VOC	0 - 300 ppm	photo-ionization detector
HC (hydrocarbons)	0 - 2000 ppm	NDIR
O_2	0 - 25 %	electrochemical
PM optical	0 - 500000 Mm^{-1}	635 nm photometer
PM red light absorption	0 - 500000 Mm^{-1}	Tricolor Absorption Photometer
PM green light absorption	0 - 500000 Mm^{-1}	Tricolor Absorption Photometer
PM blue light absorption	0 - 500000 Mm^{-1}	Tricolor Absorption Photometer
TAP flow	0 - 250 sccm	Tricolor Absorption Photometer
Undiluted sample flow	0 - 3000 sccm	mass flow sensor
Filter 1 flow	0 - 2000 sccm	mass flow sensor
Filter 2 flow	0 - 2000 sccm	mass flow sensor
Diluted sample flow	0 - 2000 sccm	mass flow sensor
Dilution flow	0 - 2000 sccm	mass flow sensor
RH	5 - 95 %	capacative
Sample temperature	0 - 150 ^oC	LM35
Probe nozzle temperature	0 - 1000 ^oC	Type K thermocouple
Auxiliary temperature	0 - 1000 ^oC	Type K thermocouple
Pitot tube differential pressure	0 - 250 Pa	solid state transducer
Atmospheric pressure	50000 - 102000 Pa	solid state transducer
Battery voltage	0 - 30 V	ADC
Stack velocity	0 - 20 m/s	calculated
Nozzle velocity	0 - 20 m/s	calculated
Dilution Ratio	0 - 20	calculated
PM mass on filter	0 - 1000000 ug	calculated

2 Components

The Possum sampling kit consists of the sensor box, sampling probes, and accessories.

2.1 Sensor Box

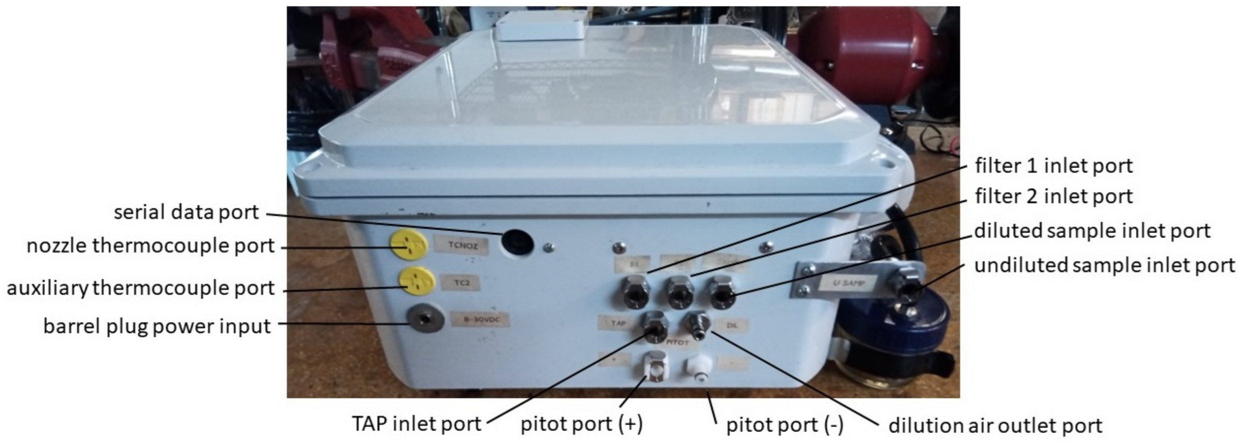


Figure 1: Right side of sensor box

Figure 2: Back of sensor box

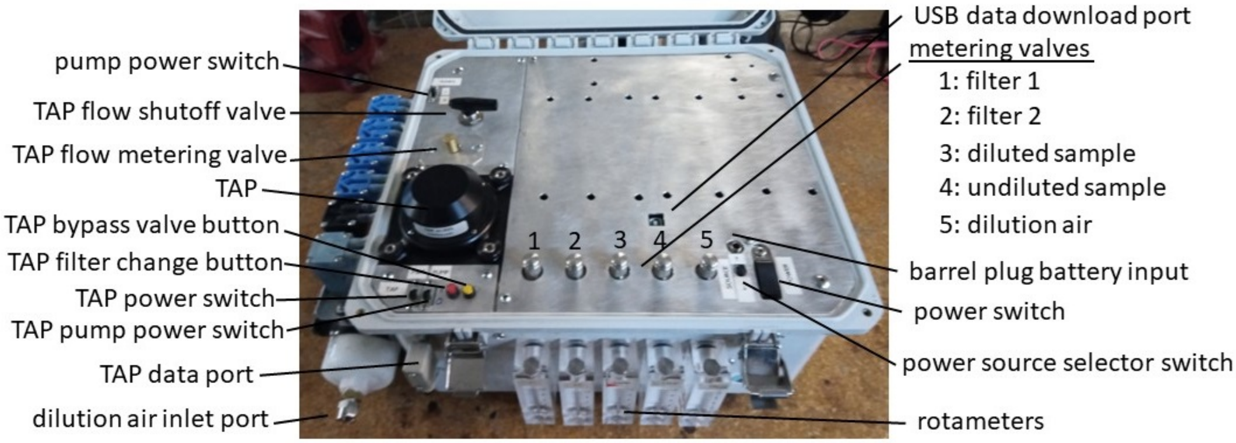


Figure 3: Inside panel

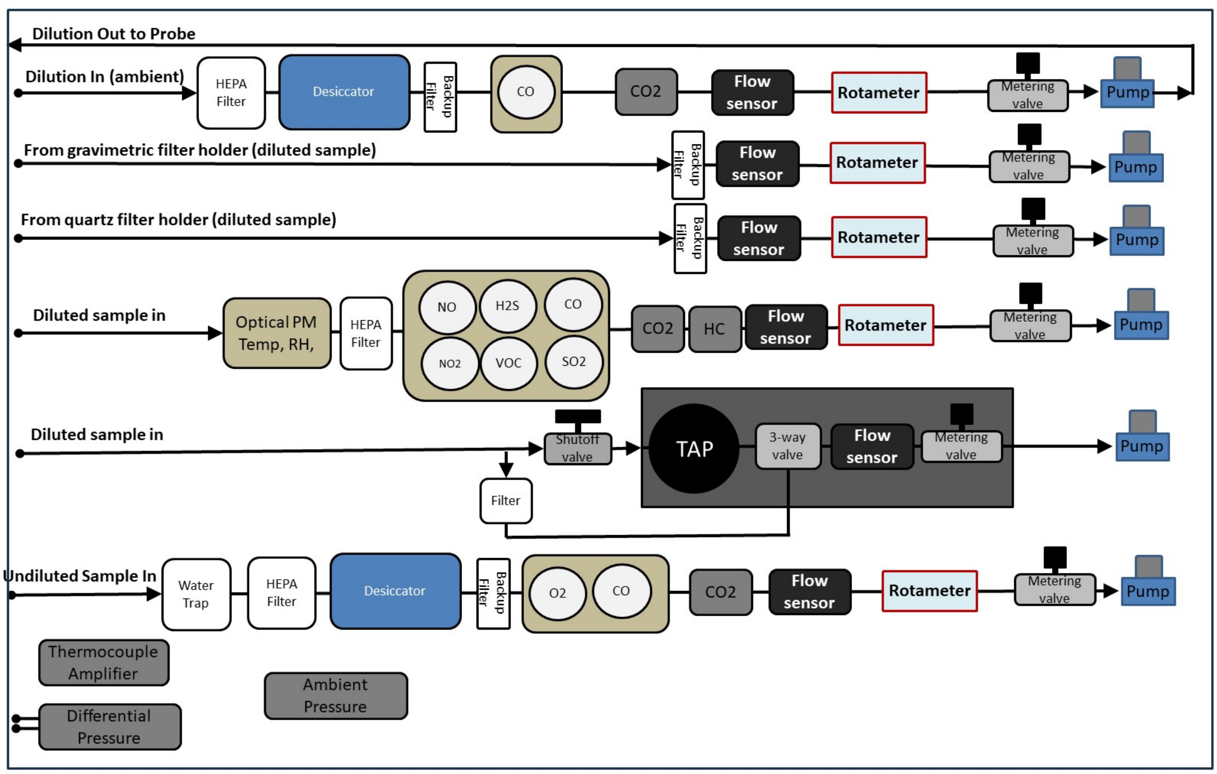


Figure 4: Sensor box flow schematic

Table 2: Accessories for LBNL, January 2024.

Number in Figure	Item	Purpose/Note
1	computer	with MusaPlotter software
2	computer AC power supply	
3	SpongeBob SquarePants carrying case	
4	AC power supply	12VDC adapter
5	battery chargers (11.1 V Li-ion)	
6	serial DIN-RS232 adapter	
7	RS232 serial data cord	
8	USB-RS232 adapter	
9	USB data download cord	
10	USB mini firmware programming cord	
11	serial-USB wireless transmitter pair	
12	hand pump vacuum gauge	for leak testing
13	gas sensor calibration tube	
14	HEPA filter	for sample inlet during warm-up
15	white tubes	for vacuum gauge and bubble meter
16	spare quick connect fittings, caps, and plugs	
17	tweezers	for handling filters
18	Kestrel weather meter	
19	multi-tool (pliers, knife, screwdriver)	
20	safety masks	for safety
21	bubble meter (AP Buck flow calibrator)	for setting and calibrating flows
22	spare HEPA filter	undiluted sample train

2.2 Accessories

2.3 Chimney Probe

2.4 Open Plume Probe

3 Software

3.1 MusaPlotter Software

The sensor box data acquisition system outputs UART serial data that can be read by serial port terminal software with the following settings:

baud: 9600
bits: 8
parity: none
stopbits: 1

Specialized Linux plotter software exists for the Possum that provides a user-friendly GUI for plotting real-time data, calibrating, and configuring instrument settings.

3.1.1 Launching the Software

Connect the sensor box data port to the computer using the RS-232 DB9 cord, RS-232/USB adapter cord, or USB wireless transmitter.

To start the plotter software, double click the **MusaPlotter** icon on the desktop of the Possum computer.

Once the software opens, select the serial port. The RS-232 serial port is /dev/ttyS0. The USB serial port is usually /dev/ttyUSB0, but the port number will increment if the USB adapter is plugged into the computer multiple times during one session. Try /dev/ttyUSB0 first, and if that doesn't work then try USB1, 2, 3, etc. You can also manually write a port name in the box instead of using the drop down menu. To determine the correct port number, plug in the USB device, then open a terminal by pressing <ctrl><alt>t and enter `dmesg` at the command line. This command shows driver messages for the operating system. The port name is printed in the last line of the dmesg output:

```
[ 1619.392136] usb 1-2: FTDI USB Serial Device converter now attached to ttyUSB0.
```

3.1.2 Plot Mode

Once a serial port connection is established the plot screen will open. If there is no data connection with the sensor box, or if the sensor box is powered off, then the plot screen will open like the following:

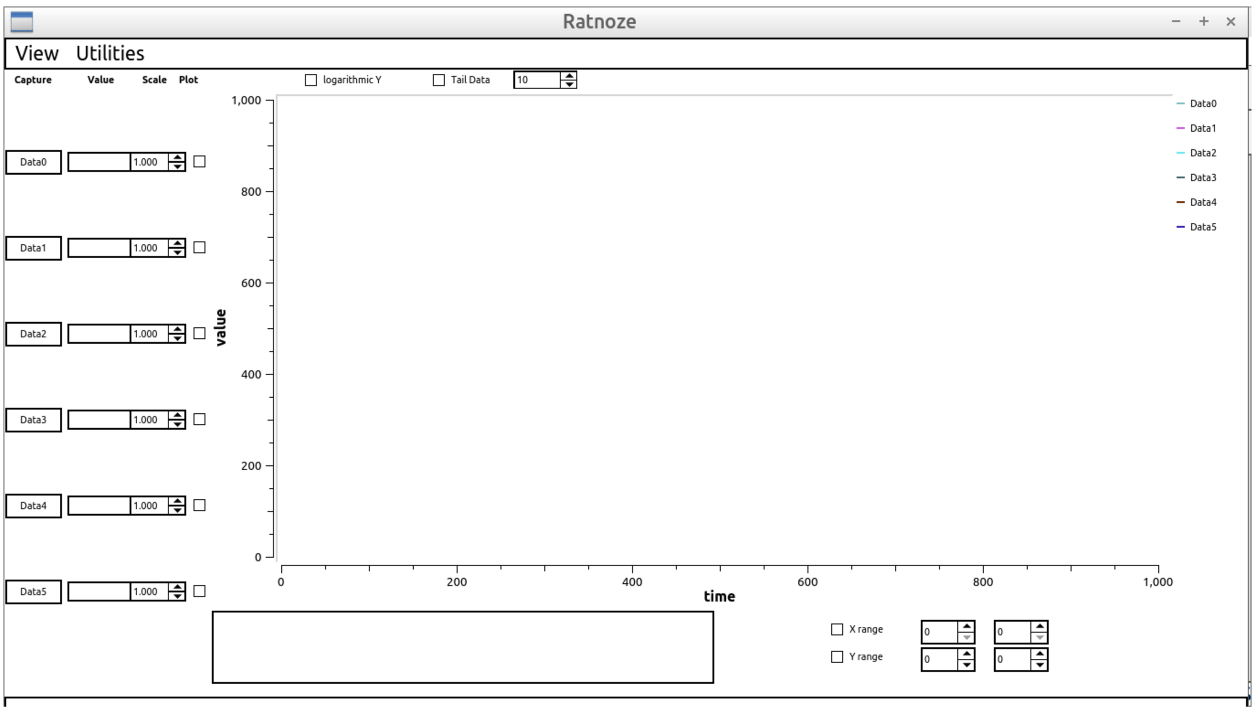


Figure 5: Default plot screen with no incoming serial data.

Power on the sensor box (if it is not already on) to populate the plot screen with the data stream.

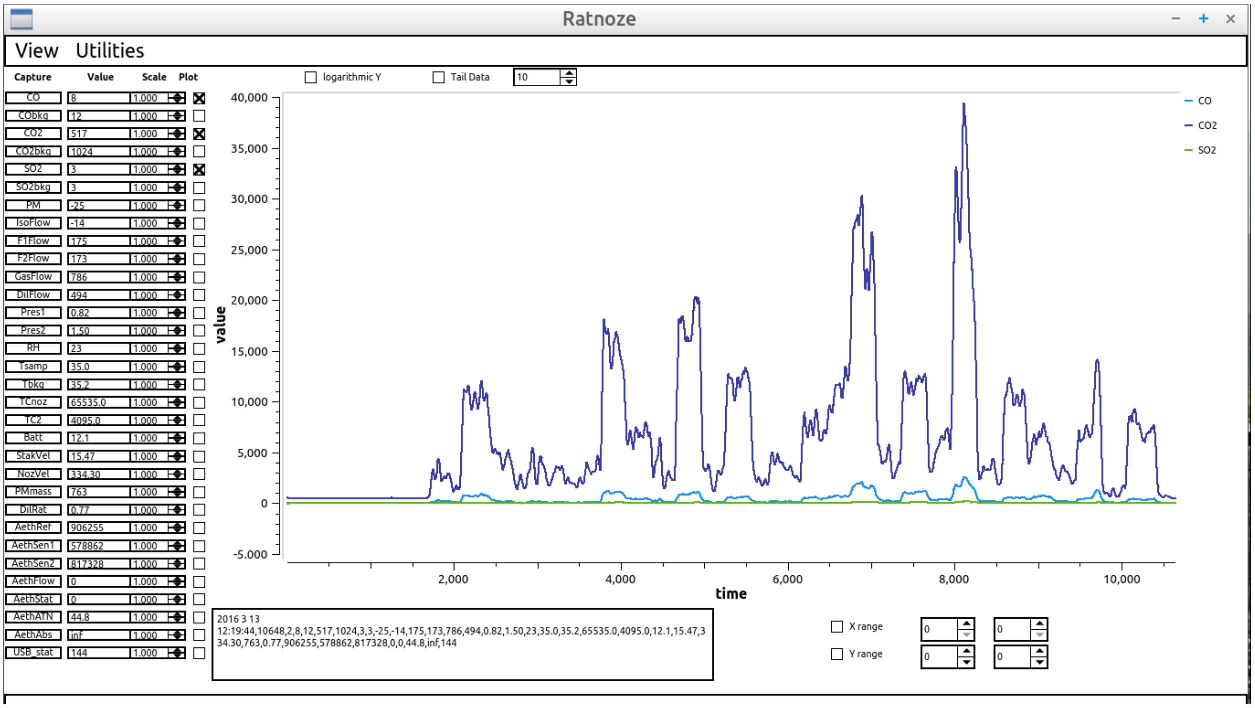


Figure 6: Plot screen. X axis is seconds elapsed since the sensor box was powered on or reset.

Data channels are displayed on the left.

The **Capture** column displays the channel names.

The **Value** column displays the channel values. Click a channel name in the **Capture** column to "capture" a reading. The value box will turn yellow and display the captured reading, which is a 10 second average. Click the channel name again to release the captured reading. The value box will turn back to white and resume displaying current values.

The **Scale** column allows you to apply a scaling parameter to the plotted data channel.

The **Plot** column has check boxes to select which channels are plotted.

The **logarithmic Y** check box will convert the Y axis to a logarithmic scale.

The **Tail Data** check box will set the X axis to plot the most recent points. Enter the tail data length in the adjacent box.

The **X range** and **Y range** check boxes in the bottom right set the X and Y axis to the minimum and maximum values defined in the adjacent two boxes.

The large box near the bottom of the screen shows the raw data stream. If the USB connection is lost, the box will display "port in use". If this happens, unplug the USB device, plug it in again, and restart the Musaplotter software.

3.1.3 Terminal Mode

Terminal Mode replaces the plot window with a terminal that shows the raw data stream, which is used to send commands to the sensor box to update operating parameters. To enter Terminal Mode, select the **View** tab and check the **Terminal Mode** box. Place the cursor in the bottom box to send commands. Three line ending options are listed to the right of the box. **LF only** will add a line feed character to every command that is sent. This is the default option which is required to communicate with the Possum sensor box. **RTN only** will add a carriage return character to the end of commands. This option is required to communicate directly with the CO2 sensors. **RTN and LF** adds a carriage return and line feed. This option is required to communicate directly with the HC sensor. To exit out of Terminal Mode and return to Plot Mode, select the **View** tab and uncheck the **Terminal Mode** box.

Figure 7: Terminal mode.

3.1.4 Calibration Mode

Calibration Mode provides an interface for calibrating sensors. To enter Calibration Mode, select the **View** tab and toggle **Cal Mode**.

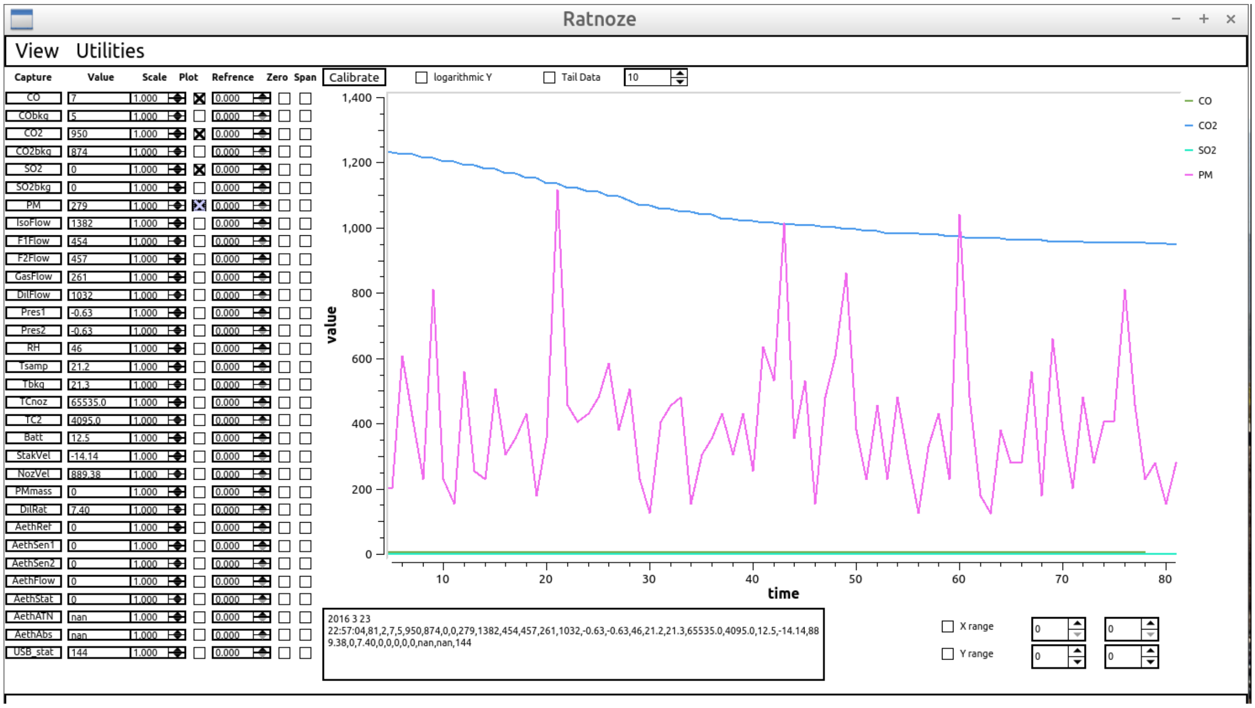


Figure 8: Calibration mode.

Calibration Mode adds three columns to the left of the plot window. The **Reference** column has boxes to enter reference values for performing calibrations of desired channels. The **Zero** column has check boxes to select a zero offset calibration for desired channels. The **Span** column has check boxes to select a span calibration for desired channels. The **Calibrate** button performs calibrations for each channel that has a zero or span box checked.

To "zero" a sensor, expose the sensor to a zero reference reading, capture a reading by clicking the channel name, select the Zero check box, and then press the Calibrate button. Once the calibration button is pressed, the program will switch to terminal mode and send a series of commands to update the zero offset (B parameter).

The sensor can be zeroed using a non-zero reference reading. For example, the CO2 sensor can be zeroed in ambient air at 400 ppm. To zero a sensor using a non-zero reference, just enter the reference reading in the **Reference** box.

To set the span of a sensor, expose the sensor to a span reference reading, enter the reference value in the **Reference** box, capture a reading by clicking the channel name, select the **Span** check box, and then press the **Calibrate** button. Once the calibration button is pressed, the program will switch to terminal mode and send a series of commands to update the span (A) parameter for the selected channels.

Multiple channels can be calibrated during one calibration.

It is not necessary to capture a reading to perform a calibration. If a reading is not captured before pressing the **Calibrate** button, then the most current reading from the sensor will be used to perform the calibration. Capturing a reading provides a more accurate calibration by using an average sensor reading to filter out signal noise.

To manually adjust the zero or span calibration for a sensor without actually taking a sensor reading, capture a reading, then manually enter a value in the **Value** box and **Reference** box.

3.1.5 Utilities

Select the **Utilities** menu item to see available utilities.

Clock Sync sets the sensor box clock to match the computer clock.

Set Parameters allows you to set parameters in the sensor box EEMEM that are used to calculate the output of the NozVel, StakVel, and PMmass channels. When this utility is selected, the current parameter values will be read from the EEMEM. A box will open that shows a list of parameters, the current values, and an entry box to update the values. To change a value, enter the new value, check the Update box, and click OK.

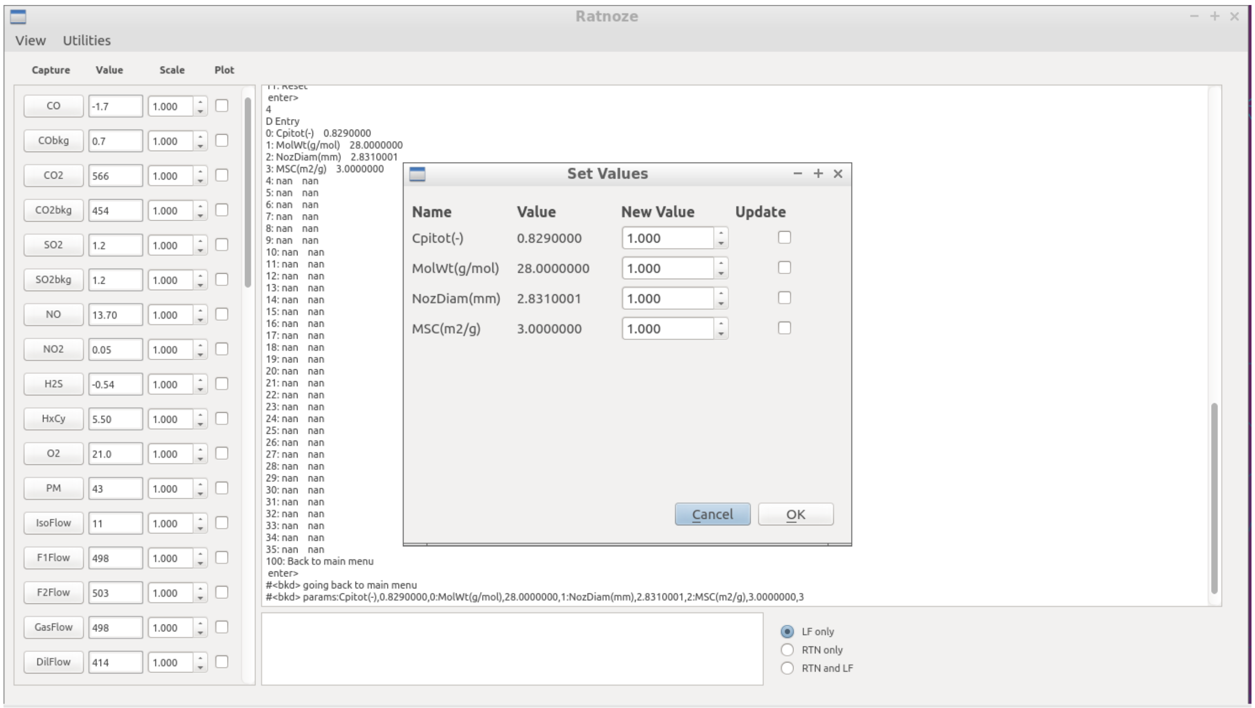


Figure 9: Set parameters utility shows the current parameter values and allows the user to update them. Cpitot is the pitot tube calibration constant. MolWt is the flue gas molecular weight. NozDiam is the probe nozzle diameter. MSC is the mass scattering cross-section used to estimate PM mass concentration from the optical scattering coefficient.

3.2 Other Software Tools

The Possum computer contains other useful software in addition to the MusaPlotter.

3.2.1 Stack Sampling Calculator

The Stack Sampling Calculator.xls spreadsheet is located on the desktop of the Possum computer. The spreadsheet has five tabs, one tab for pitot tube calculations (Figure 10), one tab for determining the appropriate nozzle diameter (Figure 11), one tab for converting flow measurements between actual and standard conditions (Figure 12), one tab for setting filter flows for appropriate filter loading (Figure 13), and one tab for USEPA velocity traverse points (Figure 14). The active cells in each sheet are color coded. Green cells are input variables that should be updated for each calculation. Yellow cells are constants and intermediate variables that should not be modified. Orange cells are output variables.

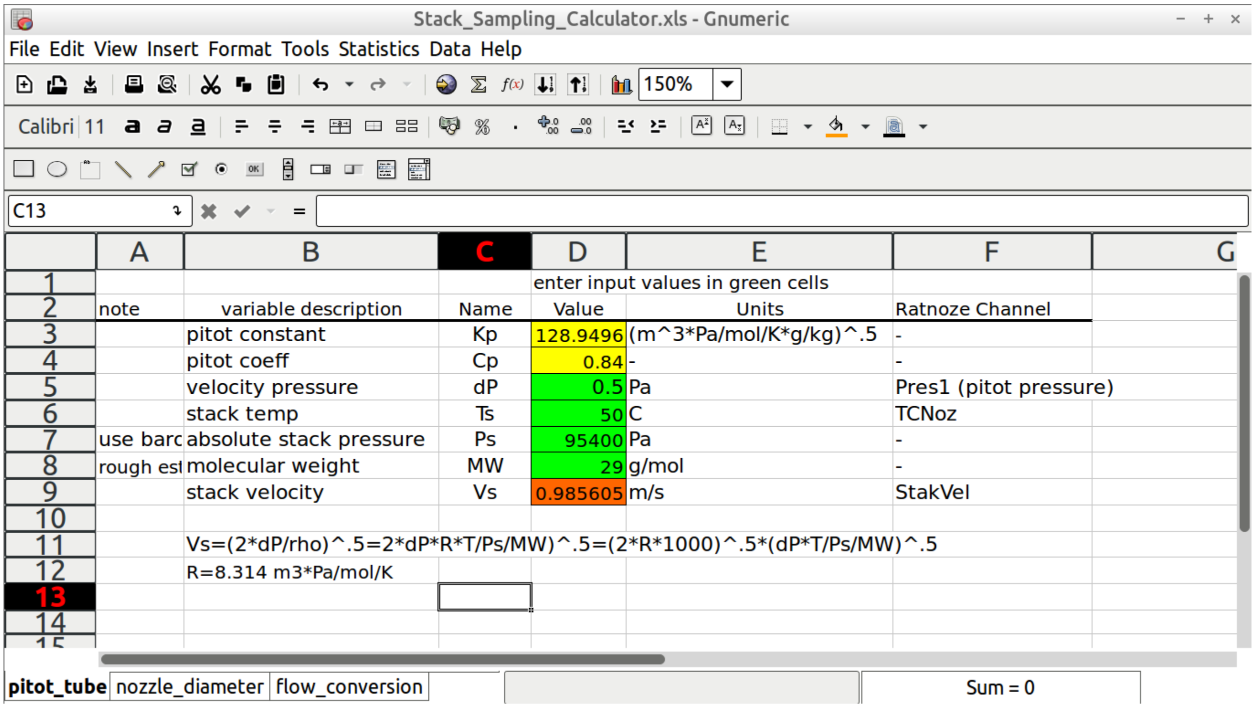


Figure 10: The pitot tube tab calculates the stack velocity using the theoretical pitot tube calculation.

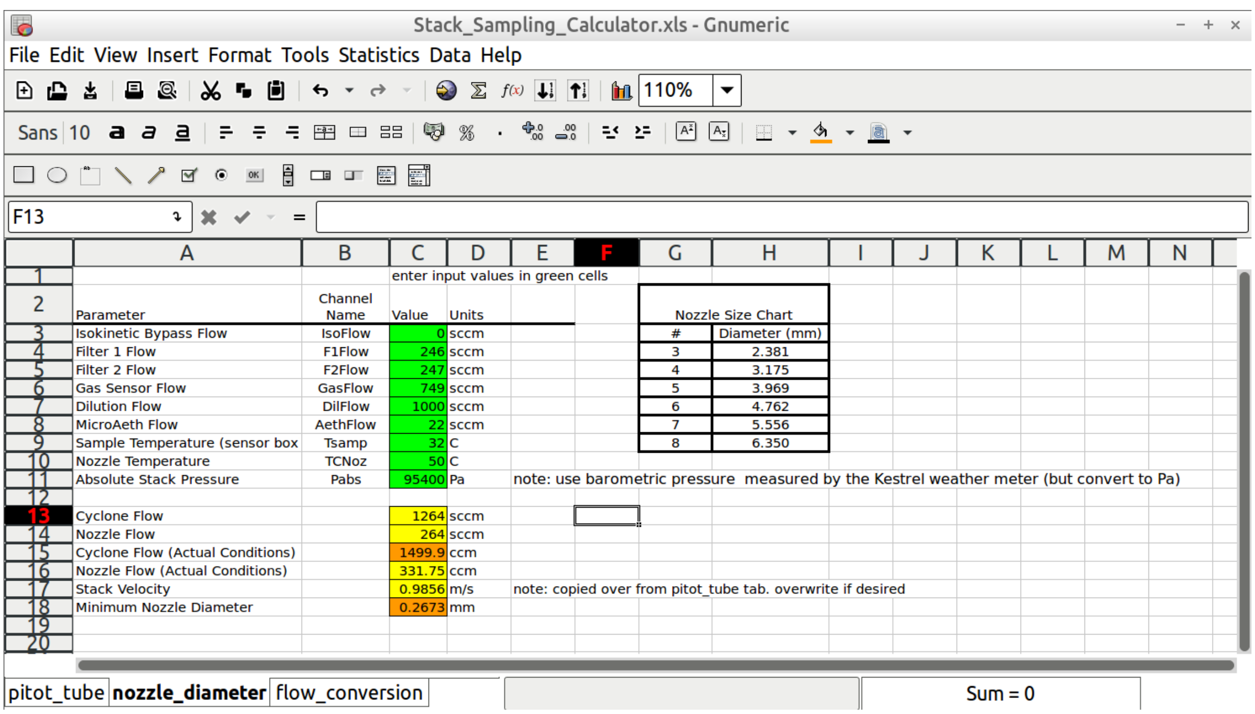


Figure 11: The nozzle diameter tab is used to determine the appropriate nozzle size. It calculates the minimum acceptable nozzle diameter for isokinetic sampling conditions and provides the nozzle size chart to choose the appropriate nozzle.

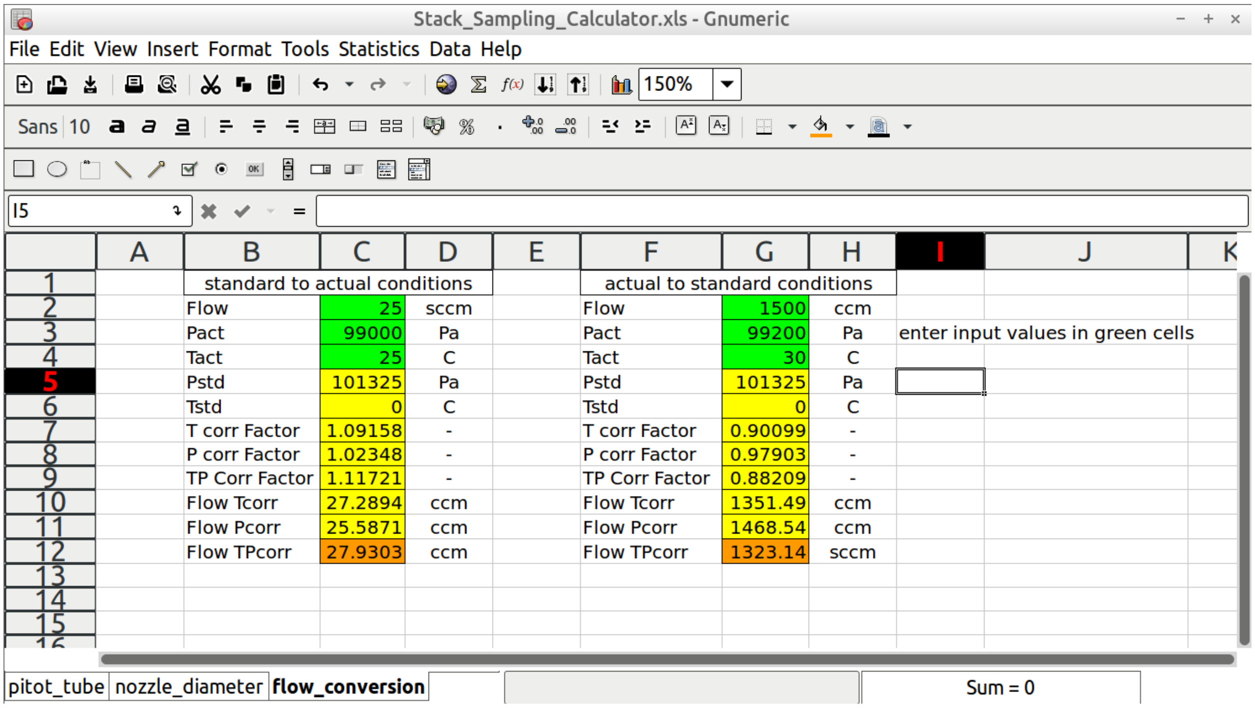


Figure 12: The flow conversion tab converts volumetric flow rates back and forth between actual conditions (ccm) and standard conditions (sccm) using ideal gas law temperature and pressure corrections.

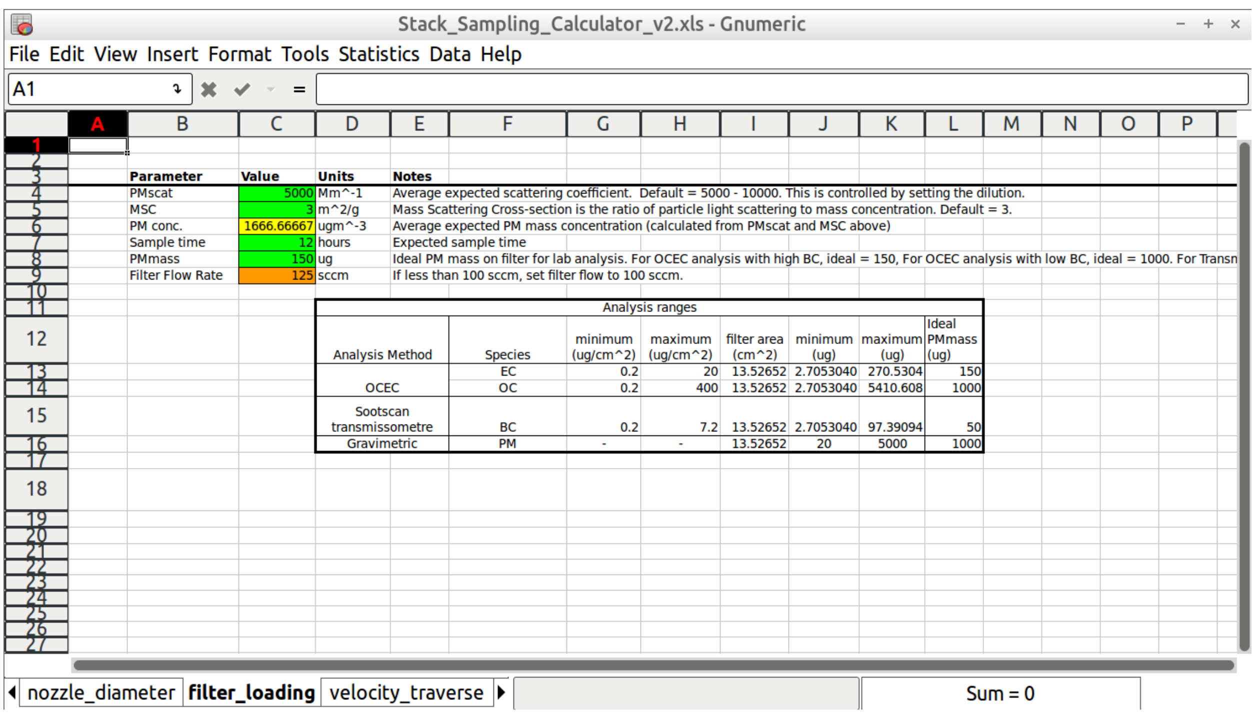
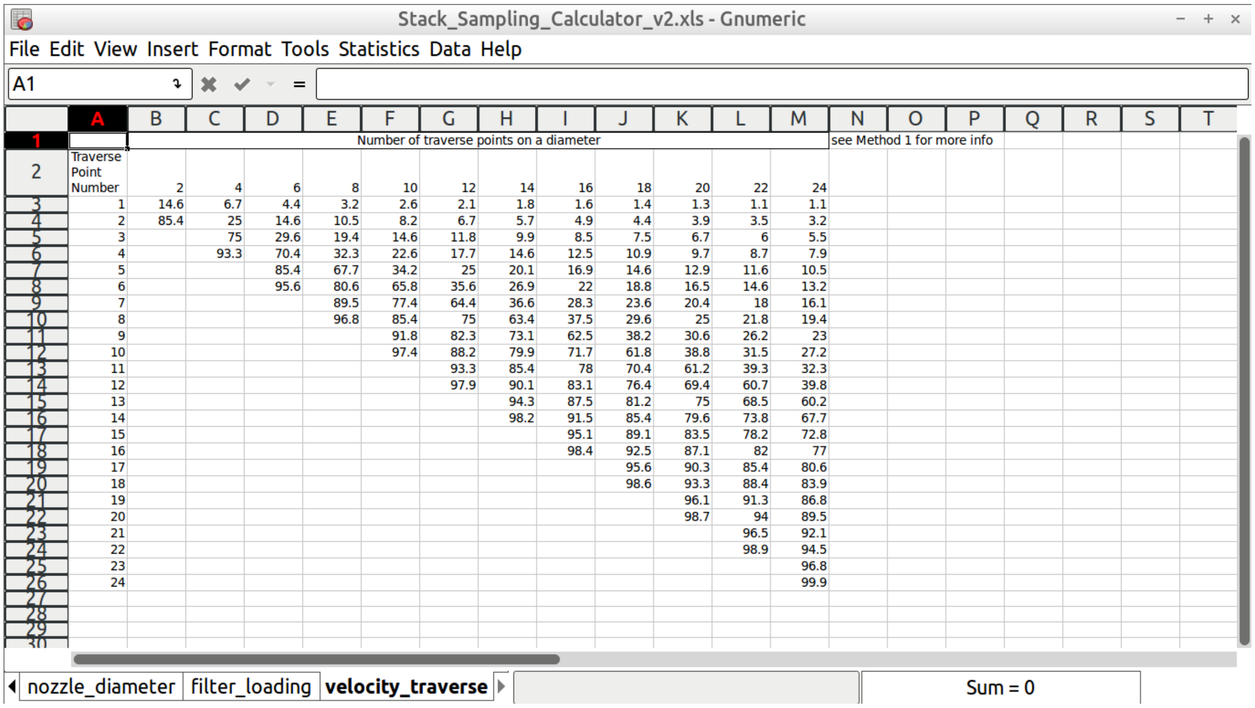


Figure 13: The filter loading tab provides a calculation to estimate the ideal filter flow rate for your particular sampling application.



Traverse Point Number	2	4	6	8	10	12	14	16	18	20	22	24
	Number of traverse points on a diameter											see Method 1 for more info
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18	16.1
8				96.8	85.4	75	63.4	37.5	29.6	25	21.8	19.4
9					91.8	82.3	73.1	62.5	38.2	30.6	26.2	23
10					97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78	70.4	61.2	39.3	32.3
12						97.9	90.1	83.1	76.4	69.4	60.7	39.8
13							94.3	87.5	81.2	75	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82	77
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												99.9

Figure 14: The velocity traverse tab provides a table of EPA traverse points as a percentage of the diameter.

4 Data Output

4.1 Data Stream

When the Possum sensor box is powered on or reset, the data acquisition system tests the connection to each sensor, and outputs startup diagnostic information. Then it prints a header of calibration parameters before starting its regular sampling loop of all sensors. The output looks like the following (with line numbers added):

1: #file begin.
2: #version: possum1.5
3: #reading eemem..#done
4: # CLOCK ERROR: no square wave
5: #testing sensor coms
6: #channels tested OK: 51
7: # num inputs: 51
8: #headers:
9: #A:,nan,10,0.1251200,0.3853200,1.0459800,0.9360200,0.5455100,38.1026001,0.1192600,0.0080500,-0.0183000,1.0000000,0.0837800,0.1927800,1.0000000,1.0000000,1.0000000,0.1312800,0.1209900,0.1121200,0.1266700,0.1172200,0.0047400,0.9754000,0.2766400,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,0.0068300,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,951.1209717,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000,1.0000000
10: #B:,nan,10,-8551.0,-8526.4,-116.5,-105.0,-5582.1,-3.0,-8535.1,-26345.0,-26249.0,-26264.0,-1760.0,3.0,0.0,-177.9,0.0,-13213.0,-13351.0,-14142.0,-13186.0,-14316.0,-921.7,53110.6,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,-0.2,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
11: #C:,nan,10,Cpitot(-),MolWt(g/mol),NozDiam(mm),MSC(m2/g),Rminrat,Gminrat,Bminrat,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan

12: #D:,nan,10,0.840,29.000,3.175,1.000,0.500,0.500,0.500,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan

13: #units:,s,10,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,ppm,Mm^{-1},,sccm,sccm,sccm,sccm,sccm,Pa,Pa,degC,degC,degC,degC,degC,degC,V,m/s,m/s,ug,-,-,-,sccm,degC,raw,raw,raw,raw,raw,raw,raw,raw,-,-,-,Mm^{-1},Mm^{-1},Mm^{-1}

14: time,seconds,ID,CO,CObkg,CO2,CO2bkg,COhi,CO2hi,SO2,NO,NO2,H2S,VOC,O2,HC,PM,RH,F1Flow,F2Flow,SampFlow,USampFlow,DilFlow,Pitot,Pamb,TCnoz,TC2,COtemp,HCtemp,HCinTemp,HCoutTemp,BattV,StakVel,NozVel,PMmass,DilRat,TAPstat,TAPspot,TAPflow,TAPtemp,drk,red,grn,blu,drkref,redref,grnref,bluref,RedRat,GrnRat,BluRat,RedAbs,GrnAbs,BluAbs

15: 20231027 10:36:35,2,10,-0.63,-0.92,487,504,-2,305,-0.01,-0.66,-0.90,1.00,-0.50,81.93,245.00,0,60.51,287.1,255.9,1011.0,471.7,512.7,0.215,101758,4095.00,18.00,24.56,27.90,6668.00,6688.00,11.77,1.93,47.28,0,0.49,0,0,-218.758,0.0,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan,nan

16: 20231027 10:36:36,3,10,-0.75,-0.54,489,507,-2,457,-0.01,-0.72,-0.93,1.00,-0.50,81.93,252.00,3,60.51,286.5,256.4,1014.7,472.0,512.6,0.181,101759,4095.00,16.75,24.56,27.90,6669.00,6689.00,11.80,1.78,47.41,0,0.49,400,3,34.240,30.1,-161.19,495408.12,139907.31,387570.44,-121.52,495261.97,139658.59,369635.56,1.00,1.00,1.05,nan,nan,nan

17: 20231027 10:36:37,4,10,-0.75,-0.54,489,507,-1,438,-0.13,-1.12,-0.90,1.00,-0.50,81.93,252.00,0,60.48,286.8,256.9,1012.2,472.1,513.7,-0.051,101729,4095.00,16.31,24.69,27.90,6669.00,6689.00,11.80,-0.94,47.34,0,0.49,400,3,34.240,30.2,-161.16,495315.62,139909.09,387595.31,-122.30,495174.34,139657.16,369656.44,1.00,1.00,1.05,501.69,-763.11,-242.93

Lines 1 - 8 are diagnostic information for startup and initialization
Line 1: Log file indicator
Line 2: Firmware version
Line 3: Indicates that calibration parameters were read from memory
Line 4: Clock test
Line 5-6: Communication test with all sensors
Line 7: Input channel count
Line 8: Indicates that data file headers will follow
Line 9: A parameters stored for each channel
Line 10: B parameters stored for each channel
Line 11: C parameters: List of parameter names used in firmware calculations
Line 12: D parameters: List of parameter values used in firmware calculations
Line 13: Physical units of each channel output
Line 14: Channel names
Line 15: First line of data in the logging loop
Line 16: Second line of data in the logging loop
Line 17: Third line of data in the logging loop.

The logging loop will continue once per second until the sensor box is powered off or the cal command is sent. The data columns in the logging loop are as follows:

1. time: date and time [yyyymmdd hh:mm:ss]
2. seconds: seconds elapsed since logging loop started [sec]
3. headID: header ID code [-] for software to identify the data stream without seeing the header
4. CO: carbon monoxide in diluted sample train [ppm]
5. CObkg: background carbon monoxide measured in the dilution air train [ppm]
6. CO2: carbon dioxide in diluted sample train [ppm]
7. CO2bkg: background carbon dioxide measured in the dilution train [ppm]
8. COhi: carbon monoxide in undiluted sample train [ppm]
9. CO2hi: carbon dioxide in undiluted sample train [ppm]
10. SO2: sulfur dioxide in diluted sample train [ppm]
11. NO: nitric oxide in diluted sample train [ppm]
12. NO2: nitrogen dioxide in diluted sample train [ppm]

13. H2S: hydrogen sulfide in diluted sample train [ppm]
14. VOC: volatile organic compounds in diluted sample train [ppm]
15. O2: oxygen in undiluted sample train [ppm]
16. HC: hydrocarbons in diluted sample train [ppm]
17. PM: particulate matter optical scattering coefficient in diluted sample train [Mm^{-1}]
18. RH: relative humidity in diluted sample train [%]
19. F1Flow: Filter 1 flow rate [sccm]
20. F2Flow: Filter 2 flow rate [sccm]
21. SampFlow: diluted sample train flow rate [sccm]
22. USampFlow: undiluted sample train flow rate [sccm]
23. DilFlow: dilution air train flow rate [sccm]
24. Pitot: pitot tube differential pressure [Pa]
25. Pamb: absolute ambient pressure [Pa]
26. TCnoz: nozzle temperature [C]
27. TC2: auxiliary thermocouple [C]
28. COtemp: diluted sample temperature measured at the CO sensor [C]
29. HCtemp: hydrocarbon sensor temperature [C]
30. HCinTemp: hydrocarbon sensor inlet temperature [C]
31. HCoutTemp: hydrocarbon sensor outlet temperature [C]
32. BattV: input power voltage [V]
33. StakVel: stack velocity [m/s]
34. NozVel: probe nozzle inlet velocity [m/s]
35. PMmass: integrated PM mass on F1 filter [ug]
36. DilRat: dilution ratio (dilution flow/nozzle flow) [-]
37. TAPstat: TAP status flag [-]
38. TAPspot: TAP filter spot number [-]
39. TAPflow: TAP flow rate [sccm]
40. TAPtemp: TAP temperature [C]
41. drk: TAP dark intensity [raw]
42. red: TAP red intensity [raw]
43. grn: TAP green intensity [raw]
44. blu: TAP blue intensity [raw]
45. drkref: TAP dark reference intensity [raw]
46. redref: TAP red reference intensity [raw]
47. grnref: TAP green reference intensity [raw]
48. bluref: TAP blue reference intensity [raw]
49. RedRat: TAP red transmissivity ratio [-]
50. GrnRat: TAP green transmissivity ratio [-]
51. BluRat: TAP blue transmissivity ratio[-]
52. RedAbs: TAP red absorption coefficient [Mm^{-1}]
53. GrnAbs: TAP green absorption coefficient [Mm^{-1}]
54. BluAbs: TAP blue absorption coefficient [Mm^{-1}]

4.2 Setup Mode (`cal` Command)

At any time during the sampling loop, the user can send the `cal` command to the sensor box to pause sampling and print the setup menu. All serial communication sent must have LF (line feed) endings.

entering calmode
1: A
2: B
3: C
4: D

5: Time
6: .Digits
7: ID
8: CO2 com
9: HC com
10: Save
11: Reset
12: CO2bkg com
enter>

The setup menu gives 12 options. Enter a menu item number to continue.

4.2.1 A Parameters

Menu item 1 returns a list of A parameters for each channel. See Appendix B to see how the parameters are used in the output calculations.

A Entry

0: CO 0.1210000
1: CObkg 0.5033500
2: CO2 1.1026599
3: CO2bkg 0.9601600
4: COhi 0.5455100
5: CO2hi 40.7929001
6: SO2 0.1192600
7: NO 0.0087600
8: NO2 -0.0142000
9: H2S 1.0000000
10: VOC 0.0675600
11: O2 0.1927800
12: HC 1.0000000
13: PM 1.0000000
14: RH 1.0000000
15: F1Flow 0.1214600
16: F2Flow 0.1166900
17: SampFlow 0.1288800
18: USampFlow 0.1288500
19: DilFlow 0.1059500
20: Pitot 0.0047400
21: Pamb 0.9754000
22: TCnoz 0.2766400
23: TC2 1.0000000
24: COtemp 1.0000000
25: HCtemp 1.0000000
26: HCinTemp 1.0000000
27: HCoutTemp 1.0000000
28: BattV 0.0068300
29: StakVel 1.0000000
30: NozVel 1.0000000
31: PMmass 1.0000000
32: DilRat 1.0000000
33: TAPstat 1.0000000
34: TAPspot 1.0000000

35: TAPflow 1069.3000488
36: TAPtemp 1.0000000
37: drk 1.0000000
38: red 1.0000000
39: grn 1.0000000
40: blu 1.0000000
41: drkref 1.0000000
42: redref 1.0000000
43: grnref 1.0000000
44: bluref 1.0000000
45: RedRat 1.0000000
46: GrnRat 1.0000000
47: BluRat 1.0000000
48: RedAbs 1.0000000
49: GrnAbs 1.0000000
50: BluAbs 1.0000000
100: Back to main menu enter>

Enter a channel number to change the parameter value. Then enter the new value when prompted. Enter 100 or <RTN> to return to the main menu. If any parameter values are changed, the changes will be temporary until they are saved to EEMEM. To do this, you must select **10. Save** from the main setup menu before exiting setup mode.

4.2.2 B Parameters

Menu item 2 returns a list of B parameters for each channel. Use the same procedure as for the A parameters to view and change parameter values.

4.2.3 C Parameters

Menu item 3 returns a list of names of constant parameters. This list can not be edited.

4.2.4 D Parameters

Menu item 4 returns a list of constant parameter values that correspond with the names listed in Menu item 3. Use the same procedure as for the A parameters to view and change parameter values.

4.2.5 Time

Menu item 5 is used to set the real-time clock in the data acquisition system. The current time is printed. Enter y to change the time or n to return to the main setup menu.

Time set
Current time: 6:19:18 3/27/16 (h:m:s d/m/y)
Change? (y/n)>

If y is entered, you are prompted for the new time:

Enter time string (YYYYMMDD HH:MM:SS)>

Finally, the updated time is read back before returning to the main menu.

4.2.6 .Digits

Menu item 6 returns a list of digit parameters for each channel. The digit parameter defines the number of digits to the right of the decimal when a channel output is printed in the data logging loop. It is used to set the resolution of each channel. Use the same procedure as for the A parameters to view and change parameter values.

4.2.7 ID

Menu item 7 is used to define the instrument ID number. This ID allows the MusaPlotter software to identify the data output format. Do not change this parameter.

4.2.8 CO2 com

Menu item 8 establishes a direct serial communication channel with the CO2 sensor. The CO2 sensor has its own internal microcontroller, and its own set of commands for calibration and temperature and pressure corrections. See documentation for the Vaisala GM111 for more information. The CO2 sensor communication requires <RTN>(carriage return) line endings. Sending ^ will stop CO2 sensor communication and return to the main setup menu.

4.2.9 HC com

Menu item 9 establishes a direct serial communication channel with the HC sensor. The HC sensor has its own internal microcontroller, and its own set of commands for calibration and temperature and pressure corrections. See documentation for the GasSense NDIR for more information. The HC sensor communication requires <RTN><LF>(carriage return and line feed) line endings. Sending ^ will stop HC sensor communication and return to the main setup menu.

4.2.10 Save

Menu item 10 saves the current parameter values to EEMEM. This action must be performed if any parameters were changed, otherwise the changes will be lost. It takes about 30 seconds for the action to complete before printing ”done” and returning to the main setup menu.

4.2.11 Reset

Menu item 11 resets the data acquisition system to begin a new sampling session.

4.2.12 CO2bkg com

Menu item 12 establishes a direct serial communication channel with the CO2bkg sensor. See menu item 8 above for more information.

5 On-board Data Logger

An on-board data logger records all data that is output from the sensor box. The data files can be accessed and downloaded from the data download port (USB square type B) on the panel (see Figure 3). The logger has two modes: data logging mode and read mode. When the logger is in logging mode, the data files cannot be accessed for viewing and downloading. When the logger is in read mode, the logger will not log data.

5.1 Data Logging Mode

The logger is normally in data logging mode as long as the USB cord is disconnected. A new data file is created every time the sensor box is powered on. The name of the file is a time stamp: ”yyyy_mm_dd_hh_mm_ss.csv”.

5.2 Read Mode

The logger switches to read mode when the sensor box is powered on while the USB cord is connected to a computer. The computer will detect the logger as a mass storage device, and the data files can be accessed and downloaded through the computer's file system browser. To return to data logging mode, remove the USB cord and power cycle the sensor box. If the USB cord is connected, the logger will remain in read mode, and it will not be able to log data. In this case, the data acquisition system will output the following error:

Read mode: SD USB connected to computer.

Conversely, if the USB cord is connected when the sensor box is already powered on, the logger will already be in data logging mode and will not switch to read mode. Always copy data files to the computer before opening them. Data files on the logger can get corrupted if the USB cord is disconnected while the files are open in a computer browser. Large files may take a minute to open.

6 Tricolor Absorption Photometer

7 Procedures

7.1 Leak Check

Each sample train can be leak tested separately by connecting a hand pump vacuum gauge to the sample train inlet port. Draw a vacuum of 10 inHg and verify the vacuum holds for 30 seconds.

If the sample train does not pass the leak test, try putting an orange quick connect cap on the sample train outlet port and re-test (the pumps in the Possum sensor box have check valves that sometimes may not hold full vacuum).

Do not connect the hand pump vacuum gauge to the pitot tube pressure ports.

7.2 Clean the Water Trap

After each sampling event, pull the water trap out of the holder, unscrew the lid, and dump the water. Wipe out the water trap jar with a tissue. After heavy use, disconnect the black tubes from the undiluted sample train inlet and HEPA filter, and blow out the tubes and water trap ports with compressed air.

7.3 Change Desiccant

7.3.1 Undiluted Sample Train Desiccant

Drierite (calcium sulfate) must be used in the desiccant chamber of the undiluted sample train. To regenerate saturated Drierite, remove the desiccant chamber from the sensor box, and spread the Drierite out thinly on metal or glass trays so the layer is one granule thick. The material in one desiccant chamber will cover approximately four square feet of tray surface. Heat the Drierite trays in an oven at 210 C for one hour. Then pour the regenerated Drierite into a glass jar with an air-tight lid.

Bone dry Drierite will adsorb CO2. Therefore, the Drierite must be partially hydrated before returning to the desiccant chamber. Once the jar of Drierite has cooled to room temperature (after several hours), spread the Drierite back out on the trays. Leave the trays on a lab counter for 5 minutes so the Drierite adsorbs some moisture from ambient air. Then pour the Drierite back into the desiccant chamber. Reinstall the desiccant chamber and leak test the undiluted sample train.

7.3.2 Dilution Air Train Desiccant

Color-changing silica gel is recommended as a desiccant for the dilution air sample train. To regenerate saturated silica gel, remove the desiccant chamber from the sensor box, and spread the silica gel out on metal or glass trays. Heat the silica gel trays in an oven at 105 C for one hour or until the color indicates it has been regenerated. Then pour the regenerated silica gel into a glass jar with an air-tight lid and let cool. Once cool, pour the silica gel back into the desiccant chamber. Reinstall the desiccant chamber and leak test the dilution air sample train.

8 Calibration

All Possum sensors have a linear output which can be calibrated with a 2 point (zero and span) calibration.

8.1 Gas Sensor Calibration

Calibration gases of the following composition are recommended:

Zero gas (for all gas sensors): Ultra-pure zero air.

Dilution air train (background sensors):
CO_2 span gas: 20000 ppm CO_2, balance air.
CO span gas: 1000 ppm CO, balance air.

Diluted sample train:
CO_2 span gas: 20000 ppm CO_2, balance air.
CO span gas: 1000 ppm CO, balance air.
SO_2 span gas: 100 ppm SO_2, balance air.
NO span gas: 50 ppm NO, balance N_2 (nitrogen).
NO_2 span gas: 15 ppm NO_2, balance air.
H_2S span gas: 20 ppm H_2S. balance air.
HC span gas: 2000 ppm CH_4 (methane), balance air.
VOC span gas: 100 ppm C_4H_8 (isobutylene), balance air.

Undiluted sample train:
CO_2 span gas: 15% CO_2 (150000 ppm), balance air.
CO span gas: 8000 ppm CO, balance air.
O_2 span gas: ambient air.

All recommended span gases (except CO_2) are hazardous. In order to prevent exposure, the calibration must be performed with the sensor box located in a fume hood, or tubing must be connected to the sample train outlet ports to route calibration gas to a fume hood.

The gas sensors have a T90 response time of 30 - 120 seconds. It is recommended to expose the sensors to calibration gas for 5 - 10 minutes to ensure a full response when calibrating. Each sensor calibration should consume 5 - 10 liters (at standard conditions) of each calibration gas.

8.1.1 Calibration Preparation:

1. Place the sensor box in a well ventilated fume hood.
2. Perform a leak test on the sample trains that will be used in the calibration.
3. Power on the sensor box, connect to the computer, and warm up for at least 30 minutes.
4. The sample train flow rates should be set to what they typically are during a sampling event.

8.1.2 Zero Point Calibration for O_2

The O_2 sensor does not require a zero point calibration, only a span calibration.

8.1.3 Span Point Calibration for O_2

Ambient air (approximately 21% O_2) can be used as a span gas to calibrate the O_2 sensor.

1. Sample ambient air for 10-15 minutes.
2. Perform a span point calibration for the O_2 sensor using the MusaPlotter software (See Section 3.1). Capture a reading, enter 21 in the reference box, select the span calibration box for the O2 channel, then click calibrate.
3. After the data acquisition system restarts, check that the sensor outputs the correct span reading in order to verify the calibration parameters were updated correctly.

8.1.4 Zero Point Calibration for All Other Gas Sensors

1. Connect the calibration gas tube to the desired sample train inlet port. For the diluted sample train, use the regular inlet port on the side of the sensor box (Figure 1). For the undiluted sample train, bypass the water trap, HEPA filter, and desiccant chamber, and connect the calibration gas to the dry inlet port on the back of the sensor box (Figure 2). For the dilution air train, bypass the HEPA filter and desiccant chamber, and connect the calibration gas to the dry inlet port on the back corner of the sensor box (Figure 2).
2. Supply calibration gas to the sample train at ambient pressure.
3. Sample zero gas for 5-10 minutes or until the sensor concentrations are stable.
4. Perform a zero point calibration for the sensor using the MusaPlotter software (See Section 3.1). Capture a reading, select the zero calibration box, then click calibrate.
5. After the data acquisition system restarts, check that the sensors output the correct zero reading in order to verify the calibration parameters were updated correctly, then turn off the calibration gas supply.

8.1.5 Span Point Calibration for All Other Gas Sensors

Repeat the above procedure in 8.1.4 with span gas instead of zero gas and perform the span calibration using the MusaPlotter software. Capture a reading, select the span calibration box for that sensor channel, enter the reference value in the appropriate box, and then click calibrate. Then double check the new sensor span readings before turning off the calibration gas.

When the calibration is finished, let the sensor box run for at least 15 minutes to clear the sample train of calibration gas before powering off.

8.2 Flow Sensor Calibration

The calibration can be done using a bubble meter as the reference meter along with the Stack Sampling Calculator spreadsheet.

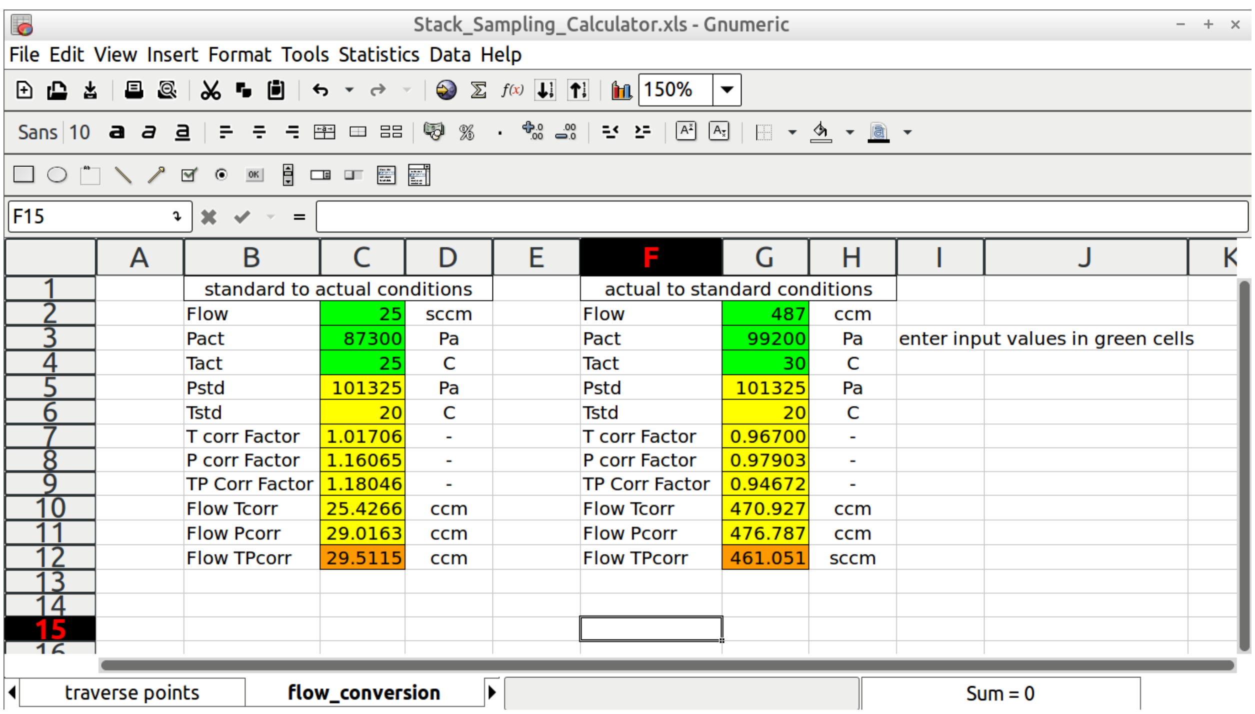
8.2.1 Zero Calibration:

1. Perform a leak test on each sample train.
2. Power on the sensor box, connect to the computer, and warm up for at least 30 minutes.
3. Use the Kestrel weather meter to measure the ambient barometric pressure and record the value.

4. Set all flows to 0 sccm by powering off the pumps (turn off the pump power switch on the left side of the panel, see Figure 3).
5. Perform a zero point calibration for all flow sensors using the MusaPlotter software (See Section 3.1). Capture a reading, select the channels to zero, then click calibrate.
6. After the data acquisition system restarts, check that the flow channels are reading 0 sccm before turning the pumps back on

8.2.2 Span Calibration:

1. Adjust the metering valves to set the flows for your particular sampling application. Repeat the following steps for each flow train:
2. Connect the bubble meter to the inlet port. Read the volumetric flow with the bubble meter. Take an average of at least three readings.
3. Capture a sensor reading for that flow channel with the MusaPlotter software. The Value box will turn yellow.
4. The bubble meter measures volumetric flow at actual conditions. This reading must be converted to volumetric flow at standard conditions using the Stack Sampling Calculator. Use the flow_conversion tab and use the column titled "**actual to standard conditions**". Enter the bubble meter reading in the **Flow** cell. Enter the barometric pressure in the **Pact** cell (remember to enter it in units of Pa and not hPa). Enter the sample temperature in the **Tact** cell. Make sure Pstd is 101325 and Tstd is 20. The corrected flow is in the orange cell called **Flow TPcorr** (Cell G12).



	A	B	C	D	E	F	G	H	I
1		standard to actual conditions				actual to standard conditions			
2		Flow	25	sccm		Flow	487	ccm	
3		Pact	87300	Pa		Pact	99200	Pa	enter input values in green cells
4		Tact	25	C		Tact	30	C	
5		Pstd	101325	Pa		Pstd	101325	Pa	
6		Tstd	20	C		Tstd	20	C	
7		T corr Factor	1.01706	-		T corr Factor	0.96700	-	
8		P corr Factor	1.16065	-		P corr Factor	0.97903	-	
9		TP Corr Factor	1.18046	-		TP Corr Factor	0.94672	-	
10		Flow Tcorr	25.4266	ccm		Flow Tcorr	470.927	ccm	
11		Flow Pcorr	29.0163	ccm		Flow Pcorr	476.787	ccm	
12		Flow TPcorr	29.5115	ccm		Flow TPcorr	461.051	sccm	

Figure 15: Convert the bubble meter reading (ccm) to standard conditions (sccm).

5. Return to the MusaPlotter software and enter the corrected flow value (in sccm) into the Reference reading box for that sensor channel. Select the span calibration box, and then click calibrate.
6. After the data acquisition system restarts, check that the sensor outputs the correct span reading in order to verify the calibration parameters were updated correctly.

8.3 PM Sensor Calibration

The PM sensor should not need to be calibrated on a regular basis. If desired, the PM sensor can be zeroed on-site before a sampling event. To zero the PM sensor, connect a HEPA filter to the sample inlet of the sensor box and zero the sensor using the MusaPlotter software. The span calibration is performed by sampling a constant concentration of smoke with the Possum and a reference meter at the same time.

8.4 Thermocouple Calibration

The thermocouple does not need to be calibrated on a regular basis. A zero point calibration can be performed by placing the thermocouple in an ice bath. A span point calibration can be performed by placing the thermocouple in boiling water.

8.5 Sample and Background Temperature Calibration

The sample and background temperature sensors do not need to be calibrated on a regular bases. They are located inside the sensor box in the gas sensor chamber. Contact Mountain Air Engineering for instructions for accessing and calibrating the temperature sensors.

8.6 Humidity Sensor Calibration

The humidity sensor should not need to be calibrated on a regular basis. The sensor is located in the PM sensor chamber in the diluted sample train. The calibration can be checked by sampling dry desiccated air and steam. The RH sensor reading should be less than 10 %RH for dry air and greater than 90 %RH for steam.

8.7 Differential Pressure Sensor Calibration (Pitot)

The differential pressure sensor should be zeroed on-site prior to every sampling event. The span calibration can be performed less frequently.

8.7.1 Zero Calibration

To zero the sensor, connect the special zeroing tube to the pressure ports to equalize the pressure. Then perform the zero point calibration using the MusaPlotter software.

8.7.2 Span Calibration

Calibrate the span against a standard reference manometer of the same range (0 - 250 Pa = 0 - 1 inches H2O).

8.8 Ambient Pressure Sensor Calibration (Pamb)

The ambient pressure sensor calibration is recommended annually. The calibration is performed by comparing the sensor output to a reference sensor (such as a Kestrel weather meter) at two pressure points that approximate the minimum and maximum range of operating conditions. There are two methods to obtaining a high and low pressure measurement.

One method is to physically transport the Possum to low and high elevation and take a pressure reading with the Possum and reference meter at the same time. The low elevation location should be at or near sea level. The high elevation location should be at the highest mountain top that it is practical to travel to.

Another method is to simulate high and low ambient pressure in the laboratory. The reference meter can be put inside a sealed pressure chamber, and this chamber can be connected to the ambient pressure port inside the sensor box. The pressure in the chamber can be varied using a vacuum pump. Contact Mountain Air Engineering for more detailed instructions about the experimental setup, and how to calculate the calculation parameters.

9 Chimney Sampling Probe

10 Open Plume Sampling Probe

11 Sampling Procedures

11.1 Preparation Before a Measurement

11.2 During a Measurement

11.3 After a Measurement

A Appendix: Example Data Sheet

B Appendix: Firmware Calculations

C Appendix: Data Processing