



Model 2200 Toxic Air Sampler

Operations and Maintenance Manual

Version 2.00

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Parts and Labor: For one year on all components from the date of original purchase, we will repair or replace, at our option, any defective part without charge for the part. Parts used for replacement are warranted for the remainder of the original warranty period.

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Introduction

This manual covers the installation, operation and routine maintenance of the ATEC Model 2200 Toxic Air Sampler. This instrument is a microcomputer controlled sampler that can be programmed to draw ambient air into cartridges and canisters for subsequent analysis of Volatile Organic Compounds (VOC's) and Carbonyl compounds according to the methods outlined in EPA Methods TO-14A and TO-15. The Model 2200 has been specifically designed to simultaneously collect both canister and cartridge samples using one easy-to-use instrument. The sampler can be configured with several options to provide co-located sampling of canisters and cartridges, pressurized canister sampling, and expanded canister and cartridge sampling with up to 16 additional ports. The Model 2200 uses independent mass flow controllers in each channel to accurately monitor and control the flow rate to the canisters and cartridges.

NOTE: The Model 2200 can be optionally configured with cartridge channels only. For this configuration, the information in this manual pertaining to canister sampling does not apply. Likewise, the Model 2200 can be configured with canisters only and in this case, the information in this manual pertaining to the cartridge sampling does not apply.

The Model 2200 has the following features:

- Manual leak check procedure during setup
- Automatic leak checks prior to the start of sampling
- Cartridge flow rate and volume, and canister flow rate and pressure logged during sampling
- Canister pressure and flow, and cartridge flow rate monitored for out of tolerance conditions
- Auto zero of mass flow controllers

- Software calibration of mass flow controllers and pressure transducers
- On screen Standard Operating Procedures provide step-by-step guidance for operators during instrument setup and post sample data retrieval
- Expansion capability of up to 16 cartridges or canisters
- Duplicate sampling with independent mass flow controllers (maximum of four independent channels)
- Auto sense feature only uses canisters that have not been sampled
- Sub-ambient or pressurized canister sampling
- User selectable final canister pressure
- 7" WVGA color touch-screen with FreeScale microprocessor
- Optional label printer to provide QA labels for cartridges and canisters
- Data download to jump drive
- Idle channels can be programmed while sampling
- Programmable purge for main units and expansion units- flushes entire sample path prior to sampling.
- Temperature controlled ozone scrubber for carbonyl sampling
- Specially designed inlet to minimize condensation in sampling lines
- Manual mode operation to activate all components

Operating Specifications

Canister Flow Rate: Nominal 20 cc/min (Optional ranges available).
Accuracy $\pm 2\%$ FS

Cartridge Flow Rate: Nominal 2 liters/min (Optional ranges available).
Accuracy $\pm 2\%$ FS

Canister Pressure
Measurement Range: 0-30 PSIA. Accuracy $\pm 0.25\%$ FS
0-50 PSIA. Accuracy $\pm 0.25\%$ FS (pressurized option)

Maximum Canister
Filling Pressure: 2 psi below ambient; 30 psia (pressurized option)

Canister Channels: Maximum 2 independent channels. One channel is expandable with optional 8 or 16 port Expansion Module.

Cartridge Channels: Maximum 2 independent channels. One channel is expandable with optional 8 or 16 port Expansion Module. One blank position.

Power: 115VAC. Maximum 5 Amp

Inlet: $\frac{1}{4}$ " OD tubing connector

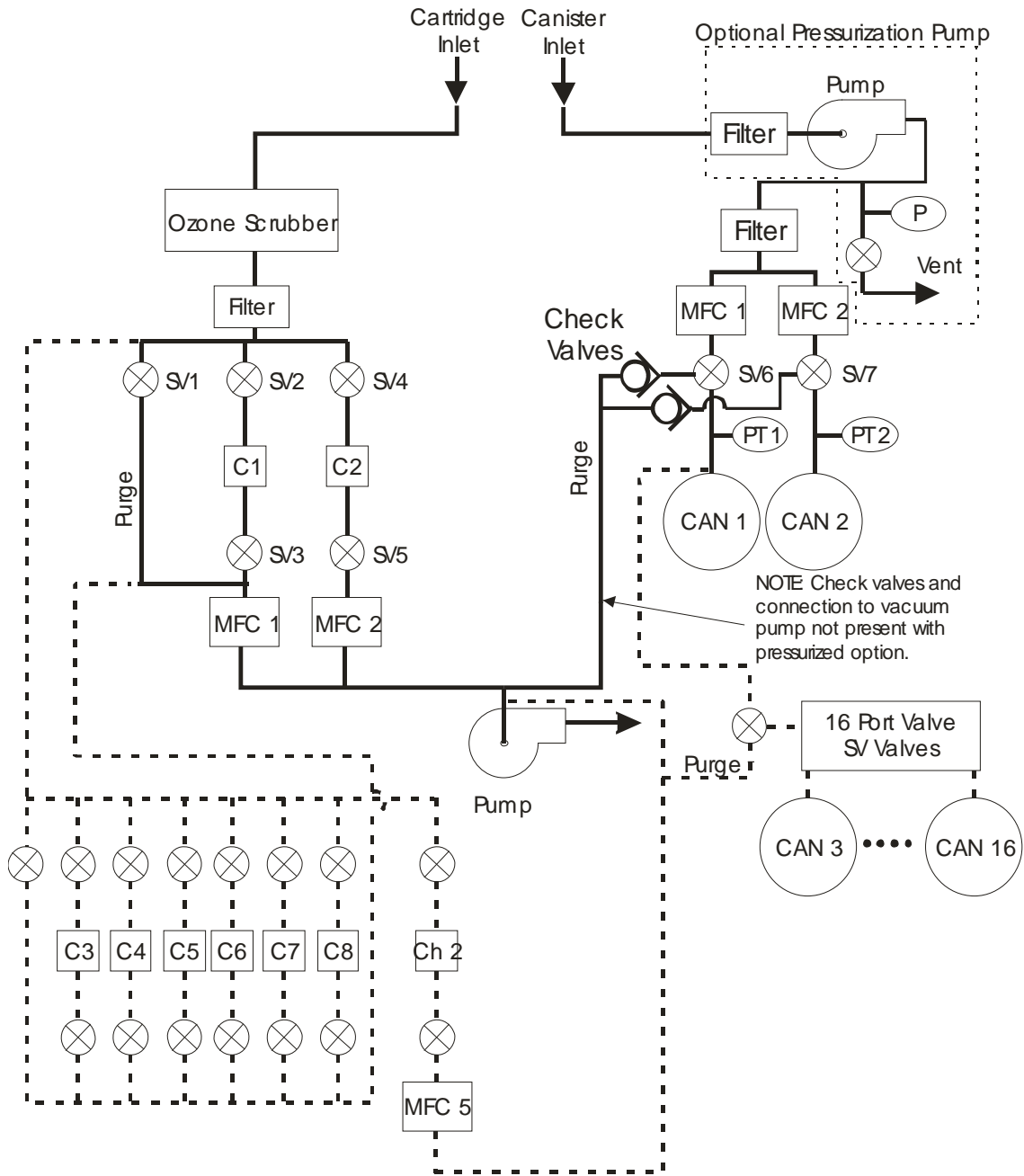
Cartridge Connections: Polypropylene Luer fittings

Canister connections: $\frac{1}{8}$ " OD tubing connector

Construction Materials: Sample air exposed to stainless steel and Viton in canister section; and stainless steel, Viton, KI coated copper, PFA Teflon, TFE Teflon, and polypropylene in cartridge section.

Sampler Components

This section describes the general operation and major components of the ATEC Model 2200. Figure 1 is a schematic diagram of the sampler with co-located sampling option (two sub-ambient canister and two cartridge channels) and optional multi-port expansion units for canister and cartridge sampling. The Model 2200 is essentially an instrument that contains a separate dual channel (when configured for co-located sampling) canister and dual channel cartridge sampler which can be programmed using a common internal computer. This configuration requires less space and allows faster, easier and more accurate programming of sampling schedules and facilitates data retrieval.



Model 2200 Flow Schematic with Canister and Cartridge Expansions

Figure 1.

There are separate ambient air inlets to provide flow to the canister and cartridge sections. An internal vacuum pump is used to draw air into the inlets

and through the cartridges during sampling. This vacuum pump also draws air through both the canister and cartridge flow paths using a by-pass solenoid valve (SV1) that is opened prior to sampling to purge the sampling lines. During sampling, the vacuum in the canisters provides the differential pressure for air to flow through the canister section (sub-ambient sampling). For pressurized canister sampling, an internal stainless steel pump with a Viton diaphragm is mounted in the inlet to provide the differential pressure to fill the canisters above ambient pressure. A separate internal filter is mounted in the canister and cartridge sample paths to remove ambient particulates. The cartridge flow path also contains a heated KI coated copper tube denuder to remove ozone. The flow rate to each canister and cartridge is measured and controlled with a separate mass flow controller (MFC1 through MFC4).

Stainless steel solenoid valves with Viton seals (SV1 through SV7) are used to isolate the canisters and cartridges from the flow path and open only during the scheduled sampling period. The solenoid valves are special low wattage valves that operate at much lower temperatures than standard valves, thereby minimizing out-gassing of volatile organic compounds from Viton surfaces. Three-way solenoid valves (SV6 and SV7) are used with the canisters so that the mass flow controllers and inlet sampling lines can be conditioned with ambient air prior to sampling. Each canister line contains an accurate pressure transducer (PT1 and PT2) to measure the pressure within the canister. The pressure is periodically recorded during sampling to document the filling rate of each canister.

An internal microcomputer provides control for the automated sampling. A touch screen display allows operator input and shows sampling schedules and data.

Figure 2 is a picture of the interior of the Model 2200-2 showing the sampler components which consists of the following:

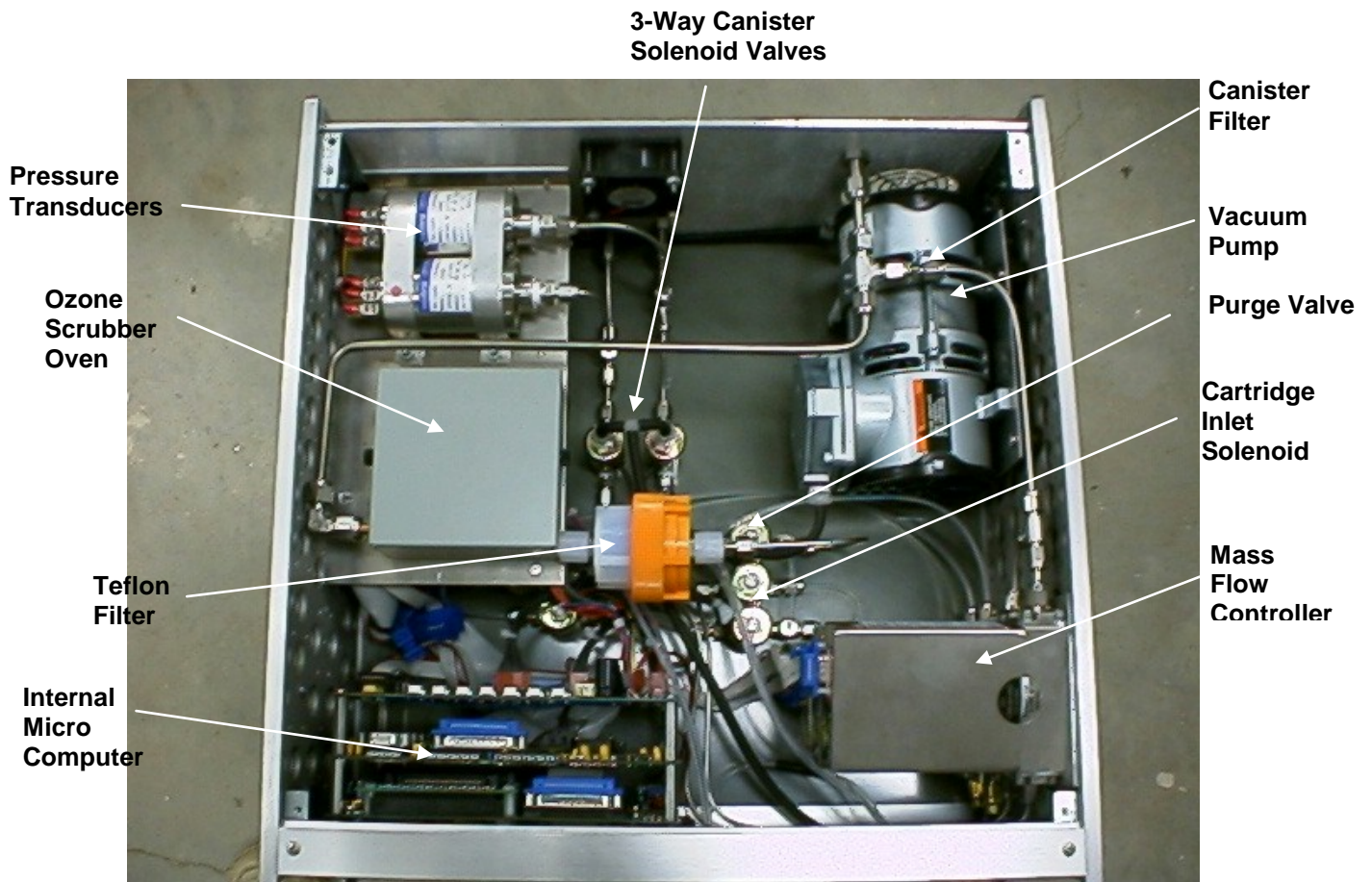


Figure 2. Model 2200 Internal Components

Inlets

External sampling lines (one for canister sampling, one for cartridge sampling) attach to the rear of the sampler using the ¼ " Swaglok bulkhead fittings.

Canister connections

Canisters are connected to the sampler using the 1/8" Swaglok fittings mounted on the rear panel. For a duplicate canister sample, attach a Swaglok tee fitting to the Canister 1 connection and attach separate lines from the tee to each canister.

Cartridge Connections

Cartridges are mounted using the Luer-lok fittings on the front panel

Canister filter

A 2 micron sintered stainless steel filter is located between the inlet and canister mass flow controllers to remove particulates from the air stream

Cartridge filter

A medium porosity (5-10 micron) 47mm diameter Teflon filter is mounted in a Teflon PFA filter holder located downstream of the ozone denuder to remove particles from the sample path.

Ozone scrubber

An ozone scrubber consisting of a ¼" OD copper tube, 36" long, which has been internally coated with potassium iodide (KI), is located downstream of the sampling inlet. The scrubber is mounted in an insulated heater, which is maintained at a temperature of $50\pm 0.5^{\circ}\text{C}$. The temperature is controlled and monitored by the internal computer.

Solenoid valves

Normally closed 2-way solenoid valves are used for each cartridge channel. Valves are located upstream and downstream of each cartridge. During normal sampling, both solenoid valves are opened. A leak check is performed during the first 20 seconds of each sampling interval. During leak check, the upstream solenoid valve is closed and the entire sampling line, downstream solenoid valve, cartridge, and flow controller are evacuated by the vacuum pump. If a small leak exists, the flow meter will detect the flow. During automatic operation, the microcomputer will set an error status if the flow exceeds a preset tolerance. A by-pass solenoid valve is located in parallel with the sampling valves to provide a purge flow to condition the sample lines prior to sampling. The purge flow is controlled using the cartridge Channel 1 mass flow controller.

A three-way solenoid valve is used to isolate each canister and corresponding pressure transducer from the flow path. When the valve is not activated, the sample path is connected to the vacuum pump, which pulls air through the inlet, filter, mass flow controllers and three-way solenoid valves to purge the entire sample path. When the solenoid valve is activated, the sample path is connected directly to the canister.

Mass flow controllers

A separate mass flow controller is used to measure and control the flow rate to each canister and cartridge. Various ranges of flow controllers can be installed depending on the required sampling flow rate. The control set point and output are interfaced to the internal computer. The mass flow controllers are zeroed prior to sampling to increase measurement accuracy.

Pressure Transducers

A precision pressure transducer is used to monitor the absolute pressure in each canister. The pressure transducers have a full-scale range of 0-30 psia. The output of each pressure transducer is interfaced to the internal computer.

Vacuum Pump

An internal diaphragm vacuum pump is used to draw air through the Model 2200 for purging and sampling. The pump is rated for continuous duty and can maintain a maximum vacuum level of 24 in Hg. The pump provides sufficient vacuum to simultaneously sample two DNPH cartridges at a flow rate of 1 lpm. Maximum flow rate depends on the flow resistance of the cartridges.

An optional stainless steel pressure pump with a Viton diaphragm is mounted in the canister flow path downstream of the inlet for pressurized canister sampling. The pressure, which is adjusted with a needle valve and pressure gauge on the front panel, is set to 5 psi above the final canister pressure.

Power supply

The Model 2200 is powered by 115VAC and activated with the on/off switch located on the rear panel. The 115VAC power is used to run the vacuum pump, canister pressure pump, ozone scrubber heater, and electronics power supply. The internal electronic components are powered using a ± 15 VDC power supply. This supply provides DC power for the mass flow controllers, interface electronics, pressure transducers, internal single board computer power supply, and cooling fan.

Sampler Setup

Upon arrival, check all shipping containers for damage and notify the shipper if damage has occurred. Carefully unpack the instrument and either bench mount or rack mount using the optional rack mount kit. Verify that the power switch on the rear panel is in the “off” position. Plug the main power cord into an 115VAC outlet. Move the power switch to the “on” position and verify that the front display becomes illuminated after approximately the first 30 seconds of operation.

The Model 2200 uses a ¼ VGA LCD color touch screen display to show current operating status and to enter information into the computer. The computer is accessed using tabs and buttons which are displayed on the screen and can be activated by finger touch or stylus. A pencil eraser also works well. The touch level of the screen can be calibrated by selecting the Touchscreen button under the **Setup** tab. Follow the directions on the screen to set the touch sensitivity. Once this is set, the buttons can be pressed using a finger or stylus.

Quarter-inch sample lines are connected to the fittings labeled “Canister Inlet” and/or “Cartridge Inlet” on the rear of the sampler. Canister connections are made to the 1/8” fittings labeled “Canister Ch.1” and “Canister Ch.2” on the rear panel. Cartridges are installed in positions labeled “Channel 1” and Channel 2” on the front of the Model 2200 using the Luer fittings. The tubing length can be adjusted for various cartridge sizes by pushing the Teflon tubing through the hole in the panel. A “Blank” location is provided to mount a field blank.

Below the touchscreen on the front panel is a USB connector for retrieving data using a jump drive, updating the system software, or attaching a USB keyboard, mouse or an optional label printer.

All components, tubing, and fittings have been cleaned prior to assembly. The completed sampler has been purged with clean humidified air prior to shipment. After unpacking the instrument and after verifying operation, the Model 2200 should be purged with humidified zero air for a minimum of 24 hours before sampling.

Display and Function Tabs

Normally the display will show the default main screen as illustrated here for a dual channel canister and dual channel cartridge configuration. This screen displays current sampling information and provides function tabs for the operator to enter operating parameters and retrieve data. The main screen displays the following:

Model 2200-2 Version 2.00				
Main Time/Date Setup Schedules Data Leak Check SOP Manual Advanced				
Monday, November 26, 2001 18:58				
East River Site				
Canister		Flow	Pressure	Status
	Ch. 1	3.34	4.31	Sampling
	Ch. 2	3.34	10.30	Sampling
Cartridge		Flow	Volume	Status
	Ch. 1	0.981	10.40	Sampling
	Ch. 2	0.992	15.21	Sampling
<input type="button" value="Abort"/>				
		Purge	0.000	Temp 50.1

Date and Time

The current date, time, and day of the week is displayed at the top of the screen.

Site Identification

A site identification label can be displayed below the time and date to identify the sampler. For example “East River Site” could be shown to identify this sampler from others used in a sampling network. This label is also displayed in the data that can be downloaded to a PC or laptop.

Canister and Cartridge Sampling Information

The canister flow rate (cc/min) and pressure (psia) along with the cartridge flow rate (liters/min) and total volume (liters) are displayed. These values are continuously updated every 10 seconds. One of the following status indicators will also be shown in each status box, depending upon the sampling conditions:

Sampling—The channel is sampling

Waiting—The channel has been programmed to sample

Purging—The channel is purging prior to sampling

Idle—The channel has not been programmed to sample

Aborted—Operator terminated sampling

Finished—A successful sample has been collected without errors

Used Can—Canister starting pressure exceeded used can limit—no sampling occurred

Leak Err—Cartridge failed the leak check on start-up

Post Leak Err—Cartridge failed auto leak check at the end of sampling

Temp Tol—Ozone scrubber temperature exceeded $\pm 5^{\circ}\text{C}$

Press Tol—Canister pressure tolerance exceeded

Flow Tol—Cartridge flow rate tolerance exceeded

Zero Tol—Cartridge MFC required excess zero compensation

*Errors---*Multiple errors, power outage, or sample aborted

Ozone Scrubber Temperature

The temperature of the ozone scrubber is displayed in the lower right hand corner of the screen. A red dot will appear next to the temperature when the heater is on.

Purge Flow Rate

When the sampler is purging prior to sampling, the purge flow rate will appear in the lower left hand side of the main screen. Normal purge flow rate is 1.0 lpm.

Abort

The **Abort** button is used to terminate sampling after purging has started. Once the **Abort** button is pressed, the channels that are sampling will be put through shut down which may take a minute or two. Also, pressing the **Abort** button will require the operator to enter a new sampling sequence to resume sampling.

Function Tabs

Several function buttons are located along the top of the screen to enable the operator to interact with the sampler, to set the date and time, enter operating parameters, input a sampling schedule, retrieve data, leak check canisters and cartridges, or set-up the sampler using the Standard Operating Procedure (SOP) option. The operation of each tab is described in the programming section.

Programming the Model 2200

The Model 2200 uses nine tab function to allow the operator to enter or retrieve information from the sampler: **Main**, **Time/date**, **Setup**, **Schedules**, **Data**, **Leak Check**, **SOP**, **Manual**, and **Advanced**. **Time/date** is used to enter the current time and date. **Setup** is used to configure the sampler and store sampling parameters. Sampling schedules are entered through the **Schedules** tab. Data can be displayed, sent to an optional label printer or downloaded to a jump drive using the **Data** tab. Canisters and cartridges are manually leak checked with the **Leak Check** option. The **SOP** tab uses a standard operating procedure to install and leak check canisters and cartridges and program sampling schedules. The **Manual** tab allows operational check out of the sampler hardware and the **Advanced** tab allows configuration of critical hardware parameters.

Time/Date

The time and date that is stored in the Model 2200 can be changed using the **Time/Date** tab. When this tab is selected, a operating system screen will appear which will allow the user to change time, date, time zone, etc. Once this window is closed, the main screen should show the changed day of the week, date, and time.

Setup

The **Setup** tab is used to input canister and cartridge operating parameters. This section is designed to allow field operators to change common operating parameters. When the **Setup** tab is selected, a screen appears which shows the following canister and/or cartridge operating parameters depending on the sampler configuration. This screen also enables recalibration of the touchscreen and the installation of software updates.

Canister Parameters

Pressure Tolerance

The Model 2200 continuously monitors the canister pressure during sampling and will produce an error flag if the pressure falls outside the pressure tolerance limit specified here. This tolerance is the difference between the expected pressure and the actual canister pressure. The sampler calculates the expected pressure based on the starting pressure, end pressure, and sampling duration.

End Pressure

The final end pressure is the desired canister pressure at the end of sampling. This value is an absolute pressure that should be determined from the atmospheric pressure at the sampling site or a value that is 5 psi below the pump pressure for the pressurized canister option. The end pressure must be at least 2 psia below this value to insure proper operation of the mass flow controllers (sub-ambient canister sampling only). The Model 2200 can be used to measure the site pressure by monitoring the canister pressure on the main screen without a canister attached.

The sampler uses the specified end pressure to calculate the necessary flow rate to fill the canister to this pressure. It must be noted that the mass flow controllers are factory calibrated to a volumetric flow rate at 760 mm Hg at 0°C (273°K). If the canister is sampled at a different temperature other than 0°C, the canister mass flow controller calibration slope must be adjusted. The filling rate and the resulting end pressure must be corrected using the ratio of sampling temperature to canister mass flow controller calibration temperature. For example, if the canister is filled at 273°K (0°C), the standard mass flow controller calibration (slope = 1.0) will provide the correct end pressure. However, if the canister is normally filled at 298°K (25°C), the canister mass flow controller calibration slope specified in Setup should be changed to 1.09 (298°K/273°K) in order to fill the canister to the specified pressure. As an

alternative to changing the canister mass flow controller calibration slope, the end pressure can be specified at a lower value to compensate for temperature. In the above example, the end pressure should be entered at 0.92 (273°K/298°K) times the desired end pressure.

Leak Rate Limit

The leak rate limit is the increase in pressure that is allowed to pass a canister during the manual leak check. This value is normally set to 0.1 psia/min.

Used Can Limit

The Model 2200 checks the pressure of each canister prior to sampling. The pressure specified in the used can limit is used to determine if a used or leaking canister has been installed. If the starting pressure is above this value, a used can error status code will be set and sampling will be stopped.

Canister and Cartridge Parameter

Purge Time

Purge time specifies the purging time before sampling either canisters or cartridges.

Cartridge Parameters

Ch.1 MFC Set Point

The sampling flow rate for the Channel 1 cartridge is specified in this box.

Ch.2 MFC Set Point

The sampling flow rate for the Channel 2 cartridge is specified in this box

Flow Leak Limit

The flow leak limit is the maximum flow rate that is allowed for a cartridge to pass either manual or automatic leak check.

Flow Tolerance

The cartridge flow rate is continuously monitored during sampling. If the measured flow rate deviates from the flow rate specified in Ch.1 MFC or Ch.2 MFC Set Point by this amount or more, an error status for flow tolerance will be generated.

Data Write Interval

The Data Write Interval specifies the time interval for recording canister pressure and cartridge flow rate data. The minimum time interval is 5 minutes.

Site Label

Touching the site label box brings up an alphanumeric keypad that can be used to input a site specific label (e.g. East River Site No. 2) that appears on the main screen. This label will also appear in the data downloaded to a PC or laptop.

Set

Pressing the **Set** button saves the data that was entered in the Set-up screens and returns the program to the main screen.

Update

If the **Update** is pressed, the sampler searches for the presence of a jump drive in the USB connector below the screen. If the jump drive is present and has the proper updating files, the sampler software will be updated. If the update is successful, a message will appear on the screen stating that the update was successful and that the system will reboot in 15 seconds. If the jump drive cannot be recognized or it does not have the proper update files, a message will be display warning of an incomplete update and not software changes will be made.

Schedules

The **Schedules** tab is used to enter sampling schedules for the canisters or cartridges. Canister or cartridge channels can run independently or together (co-located sampling or duplicate sampling). When the **Schedules** tab is pressed, a screen appears which shows the start date, start time, and sample duration for Canister Ch.1. The values in each box can be changed by touching the text box and using the keypad or calendar to enter the appropriate values. All times are in military time format with midnight being 00:00. A 24-hour sample starting at midnight would be entered with a start time of 00:00 and a duration of 24:00 hours for the date entered in the "date" box. An identification label (e.g. Can 13420, Cart A6672) can also be entered for each canister and cartridge. This label will appear with the data to identify each sample. If a duplicate canister sample is to be taken (i.e. the Canister 1 connection on the rear of the sampler is connected to two canisters), the "with Duplicate Can" box should be checked. If only Canister Ch. 1 is to be sampled, the **Done** button is pressed and the sampler will return to the main screen.

If additional channels are to be sampled, The **Next** button must be pressed to display the schedule for Canister Ch. 2. The start date, start time, and duration can be entered for Canister Ch. 2. However, if Canister Ch. 2 is to run as a co-located sample (i.e. same sampling time as Canister Ch. 1), the box marked "Sample with Ch. 1" should be checked and the same schedule for canister Ch. 1 will be entered for Canister Ch. 2. A label for Canister Ch. 2 can also be entered in the "Run Label" box. If no cartridges are to be sampled, the **Done** button can be used to return to the main screen. If a change must be made to the Canister Ch. 1 schedule, the **Prev** button will show the previous screen.

Pressing the **Next** button will show the schedule screen for Cartridge Ch. 1. The start date, start time, duration and label must be entered for this channel. However, if Cartridge Ch. 1 is to run at the same time as canister Ch. 1, the box

labeled “Sample with Can” should be checked and the sampling schedule for Canister Ch. 1 will be automatically entered for cartridge Ch. 1. If desired, an identification label for this cartridge can be entered in the “Run Label” Box.

If a second cartridge is to be sampled, pressing the **Next** button will show the schedule for Cartridge Ch. 2. The schedule information can be entered or the “Collocated Cartridge” box could be pressed to enter the same schedule as Cartridge Ch. 1. The **Prev**, **Next** and **Done** buttons can be used to return to the previous screen, scroll around to the first screen, or move to the main screen.

Data

The **Data** tab is used to display or download data. After sampling has been completed, the **Data** tab is touched and the “Canister Ch. 1 Data” screen is displayed. The stored data includes: canister start time and starting pressure; canister stop time and ending pressure; average, minimum, and maximum flow rate; error status, and elapsed time.

If the label printer option has been installed, a label can be printed for each channel by pressing the **Label** button. On each label the following information will be printed: start date/time, end date/time, start and end pressure or total sampled volume, average flow rate, and error flag. The error flag is the sum valve of all errors that occurred during the sample period. The error values are:

0	No Errors
1	Used Can Pressure Limit Exceeded
2	Leak Check Flow Limit Exceeded
4	Temperature Tolerance Exceeded
8	Pressure Tolerance Exceeded
16	Flow Rate Tolerance Exceeded
32	Flow Rate Zero Exceeded
64	Power Failure
128	Aborted

- 256 Post Run Leak Check Flow Limit Exceeded
- 512 Inlet Purge Line Flow Limit

The entire data set can be downloaded to a jump drive inserted into one of the USB connectors below the screen. It takes approximately 20 seconds for the operating the system to recognize the jump drive. Pressing the **Store** button will cause all available data to be transferred. The data file name has the format: *[SiteLabel_]Can1Data_DateofTransfer.txt*. This name is unique so that existing data on the jump drive will not be overwritten. Using the site label in the file name allows data from different sampler to be stored on the same jump drive. Once all the files have been received, a message will appear confirming completion of the transfer.

An example of transferred canister data file is shown below.

```

East River Site
Canister 13249
Ch. 1 Canister Started at 11/20/00 9:00:06 PM
    Starting Pressure 0.11 psia
    Flow Rate Set Point 3.29 cc/min
    Stopped at 11/21/00 9:00:05 PM
    End Pressure 11.68 psia
    Average Flow Rate 3.29 cc/min
    Minimum Flow Rate 0.94 cc/min
    Maximum Flow Rate 3.47 cc/min
    Flow Controller Zero 0.03 cc/min
    Error Status Pressure Tolerance Exceeded

```

Time	Can Pressure
11/20/00 9:00:17 PM	0.26
11/20/00 9:05:26 PM	0.16
11/20/00 9:10:36 PM	0.24
•	•
•	•
•	•
11/21/00 8:45:25 PM	11.61
11/21/00 8:50:25 PM	11.63
11/21/00 9:00:05 PM	11.68

The **Next** button on the 2200 Data screen will advance to the next canister or cartridge data or **Exit** can be used to return to the main screen.

The cartridge data screens follow the canister data screens. The stored cartridge data includes: start time; stop time; average, minimum, and maximum flow rate; error status; total volume sampled, and elapsed time.

An example of a cartridge data file is shown below.

Southern County Site
 Cartridge A312
 Ch. 1 Cartridge Started at 11/25/01 8:15:06 PM
 Flow Rate Set Point 1.000 lpm
 Stopped at 11/26/01 8:15:36 PM
 Total Volume 1428.05 liters
 Average Flow Rate 0.996 lpm
 Minimum Flow Rate 0.984 lpm
 Maximum Flow Rate 1.017 lpm
 Pre Start Leak Rate 0.012 lpm
 Ending Leak Rate 0.022 lpm
 Flow Controller Zero -0.003 lpm
 Error Status Temperature Tolerance Exceeded

Time	Flow Rate	Volume
11/25/01 8:15:28 PM	1.902	0.35
11/25/01 8:20:36 PM	0.997	5.47
11/25/01 8:25:36 PM	0.996	10.45
11/25/01 8:30:46 PM	0.995	15.59
11/25/01 8:35:46 PM	0.995	20.57
11/25/01 8:40:56 PM	0.996	25.72
11/25/01 8:45:56 PM	0.996	30.70
11/25/01 8:51:06 PM	0.995	35.84
•	•	
•	•	
•	•	
11/26/01 7:35:15 PM	0.997	1388.21
11/26/01 7:40:25 PM	0.996	1393.35
11/26/01 7:45:35 PM	0.995	1398.50
11/26/01 7:50:35 PM	0.998	1403.48
11/26/01 7:55:45 PM	0.994	1408.62
11/26/01 8:00:45 PM	0.995	1413.60
11/26/01 8:05:55 PM	0.996	1418.75
11/26/01 8:11:05 PM	0.994	1423.90

Power Failures

If a power failure occurs during sampling, the sampler will resume sampling based on the programmed sampling schedule. The sampling schedule and data will not be lost during a power failure. The actual sampling time will be shorter than programmed because of the power loss. Both canister and cartridge data will show a power loss error, and the pressure/time and volume/time data will show the missing sampling interval during the power outage.

NOTE: The power failure error will also be reported if the system goes through a reboot during sampling. A hardware timer is monitoring system activity and if there is no activity for 30 seconds, the system will automatically reboot. The software sees this as a power outage and will record the power failure error. Sampling will resume with a minor loss of sampling data.

Leak Check

The **Leak Check** button is used to verify the canister and cartridge connections prior to sampling. The first screen is identified as “Can Ch. 1 Leak Check” and is used to leak check the Ch. 1 canister. Before starting the check, the operator must install an evacuated can on the Canister Ch. 1 port on the rear of the sampler. After the connections have been tightened, the canister valve is opened and then closed to evacuate the connecting line, internal sample tubing, and pressure transducer up to the isolation solenoid valve. Since the tubing has a small volume, small leaks will cause a rise in the measured pressure. The automated leak check routine will sample the pressure and determine if a leak is present. Even though pressure measurements fluctuate, the program will use a least square data analysis routine to determine an accurate leak rate.

The **Start** button is pressed to begin the leak check. The leak rate box will show “testing” during the measurement period. The canister pressure measurement is shown in the lower right hand side of the screen along with the elapsed time. Testing can be stopped at any time by pressing the **Stop** button. After sampling for one minute, the calculated leak rate is shown in the leak rate box. If the test passed, the value is shown and “Passed” is displayed below the leak rate box. If the test failed, the value is shown and “Failed” is displayed below the box. When a canister fails, the test should be repeated to verify the first test. After repeated failures, the connections should be tightened again or replaced and

the leak check repeated. The **Next** button is used to advance to Canister Ch. 2. if a collocated can is to be tested.

A similar procedure is used to leak check the cartridges. After the Ch. 2 canister is tested, the **Next** button will display the cartridge “Ch. 1 Leak Check” screen. Cartridges are leak checked by turning on the vacuum pump and closing the upstream isolation solenoid valve. The downstream solenoid valve remains open to evacuate the cartridge, mass flow controller and tubing to the pump. If a leak is present, the flow controller will show a small flow. A leak is identified if the flow rate exceeds the flow rate tolerance set in the setup section.

The cartridge leak check procedure is similar to the one used for canisters. After a cartridge has been installed, the operator must press the **Start** button to begin the test. The cartridge leak check runs for 20 seconds. During this time, the vacuum pump is started and the flow rate is monitored. If the flow rate is above the leak limit at the end of the test, a “Failed” message is displayed and the leak flow rate is displayed. If a cartridge fails, the test should be repeated to verify the first test. After repeated failures, the fittings should be checked and the cartridge re-tested or replaced. The test can be repeated by pressing the **Start** button, or the next button can be used to advance to Ch. 2 cartridge testing.

SOP

The **SOP** tab provides a Standard Operating Procedure for installing, leak checking, and scheduling the Model 2200. The SOP software guides the user through the required procedures and enables inexperienced operators to successfully program the sampler.

Pressing the **SOP** tab initializes the program. The **Back**, **Next**, and **Exit** buttons are used to advance through the procedure or return to the main screen.

Initially, the program brings up a screen that requires the user to check the number of cans or cartridges to be sampled. Several screens follow which lead the operator through an automated leak check procedure. Each canister or cartridge must pass leak check or the program will not continue. After all of the cartridges and canisters have been installed and leak checked, the SOP leads the user through a scheduling procedure to program the sampling times. When scheduling has been completed, the **Next** button returns the program to the main screen. After sampling has been finished, the operator uses the **Data** tab to retrieve the collected data.

Manual Mode

A **Manual** tab is provided to allow the operator to activate any solenoid valve or pump. This mode is useful in troubleshooting and testing individual components. In addition, the flow set point of each mass flow controller can be individually set. Upon leaving the manual mode screen, all settings revert to the values used in automatic mode. The flow rate and pressure values shown in this mode are **not adjusted** by the calibration constants (slope and intercept) entered in Setup.

Advanced

Additional settings can be modified in the Advanced tab section that is accessed through the **Advanced** tab. Portions of this screen can only be accessed with a password and should only be used by individuals familiar with the operation and calibration of components used in the Model 2200. Changing the values in the Advanced Setup will alter the accuracy of the instrument.

Mass Flow Controller Calibration

The calibration of the mass flow controllers can be changed by entering the appropriate slope and intercept for each mass flow controller. See Appendix A.

Pressure Transducer Calibration

The calibration of each pressure transducer can be changed by entering the appropriate slope and intercept for each pressure transducer. See Appendix A.

Mass Flow Meter Range

If the full scale range of a mass flow controller is changed, the corresponding full-scale range must be entered in the MFC Range box. This item is hardware dependent and is password controlled.

Heater Set Point

The set point of the ozone scrubber heater may be changed by replacing the value in the box marked Heater Set Point. The normal set point is 50 °C. This item is hardware dependent and is password controlled.

Purge Flow Rate

The purge flow rate can be changed by selecting a new value in the Purge Flow Rate box. The purge flow is regulated by MFC 3 and cannot be greater than the full scale range of this mass flow controller.

Pressure Transducer Range

The range of each pressure transducer must be entered in the Press 1 and Press 2 Cal boxes. This item is hardware dependent and is password controlled.

Pressure Transducer Offset

Some pressure transducers have a zero offset. The value for the offset must be entered in the Press 1 and Press 2 Off boxes. This item is hardware dependent and is password controlled.

Temp High Limit

If the sampler is in an outdoor enclosure, the cooling fan will be turned on when the enclosure temperature exceeds this limit. The fan is also activated any time the pump is on. This item is hardware dependent and is password controlled.

Temp Low Limit

If the sampler is in an outdoor enclosure, a heater will be activated if the enclosure temperature should fall below this value. This item is hardware dependent and is password controlled.

Inlet Purge Flow Limit

If the sampler has an optional inlet purge mass flow meter, an error flag will be set if the inlet purge flow rate falls below this setting. This item is hardware dependent and is password controlled.

Language

If the sampler has been configured for multi-language capability, a drop down box will be on the screen with the selection of available languages. To change to another language, select the language in the drop down box and then press the ***Exit*** button. When returning to English from another language, the system will automatically reboot.

Maintenance

This section describes routine maintenance procedures for the Model 2200 Toxic Air Sampler. All other repair work should be performed by trained personnel.

Vacuum Pump

To remove the vacuum pump from the sampler, remove the top and side covers. Remove the inlet tube and disconnect the electrical connector. Remove the four screws attaching the pump mounting bracket to the side of the sampler and remove the pump.

Inspect the pump but DO NOT at any time lubricate any of the parts with oil, grease, or petroleum products nor clean with acids, caustics or chlorinated solvents. Be very careful to keep the diaphragm from contacting any petroleum product or hydrocarbons. It can affect the service life of the pump.

WARNING: To prevent explosive hazard, do NOT pump combustible liquids or vapors with these units. Personal injury and or property damage would result.

To clean or replace the filters and/or rubber gasket, remove the five screws in the top of the unit. The filters and gasket are located beneath this top plate. Remove the filters and wash them in a solvent and/or blow off with air and replace. The gasket may be cleaned with water. Replace the filters in proper position and replace the gasket. Note that the gasket and top plate will fit in one position only.

To replace the diaphragm, remove the socket cap screws from the head of the pump. The diaphragm is held in place by two Phillips head screws. Remove screws, retainer plate, and the diaphragm. The diaphragm will fit in any position on the connecting rod. Replace the plate and the two Phillips head screws. Torque to 17- inch-pounds.

CAUTION: Do not raise any burrs or nicks on the heads of these screws. These burrs could cause damage to the inlet valve.

For replacing the inlet and outlet valve, remove the slotted machine screw that holds each valve in place. The stainless steel inlet and outlet valves are not interchangeable. Clean them with water. When replacing the outlet valve, place the new valve in location and note there is a retaining bar near the machine screw hole. This retaining bar holds the valve in position. When replacing the inlet valve, note that the valve holder is marked with an X in one corner. This X should be in the lower right hand corner toward the inlet of the air chamber. Replace the head and tighten the socket head screws. Torque to 30 inch-pounds.

WARNING: The motor may be thermally protected and can automatically restart when the overload resets. Always disconnect the power source before servicing. Personal Injury and/or property damage could result.

Do not attempt to replace the connecting rod or motor bearings. If after cleaning the unit and/or installing a new Service Kit, the unit still does not operate properly, contact your representative, the factory, or return the pump to an authorized Service Center.

Cartridge Filter

The operator should periodically replace the Teflon filter located in the cartridge sample path. The replacement frequency will depend on site conditions. The filters must be replaced when the flow rate through the cartridges cannot be maintained. However, it is recommended that the filter be replaced before this condition exists. The operator should periodically check the filter and determine when it needs to be replaced. To replace the filter, turn off the main power to the sampler, remove the four screws that fasten the top to the sampler, slide the top towards the rear of the instrument and remove. Loosen the tubing nuts on each end of the filter housing and remove the housing. Remove the filter by

removing the retaining ring on the filter using the hand wrenches supplied with the sampler. Replace the filter with a 5 to 10 micron Teflon filter and replace the filter housing in the sampler.

Canister filter

The operator should periodically replace the 2 micron sintered stainless steel filter in the canister flow path. The filter must be replaced when the canister flow rate cannot be maintained. Site conditions will determine the replacement frequency. Remove the Filter assembly in the sample line at the ¼” Swaglok “T” fitting on the canister side of the “T” (Refer to Figure 1). Using a wrench, disassemble the assembly to expose the pressed-in filter disk. Using a small punch or rod, push the filter disk out the end of the fitting and replace with a new disk. The new disk may need to be tapped into the fitting with a clean hammer.

Ozone Scrubber

The ozone scrubber should be replaced after approximately 100,000 ppb ozone hours of either sampling or purging at 1 lpm. This is generally every 6-12 months depending on the sampling frequency. The operating life in hours can be estimated by:

$$\text{Life (hrs)} = 100,000 / \text{Average Ozone concentration at site.}$$

The ozone scrubber is replaced by removing the top cover on the sampler and removing the ¼” stainless steel sample line with fittings and the Teflon filter holder on each side of the scrubber. Remove the two retaining knobs on the heater cover and remove the cover, exposing the heater block and copper tube denuder. Remove the insulation surrounding the heater block and carefully remove the denuder. Install a new denuder and replace the insulation and heater cover. Replace the sample lines and Teflon filter. Leak check the sample path by using the procedure described in the Sampler Leak Check Procedure section.

Mass Flow Controller Calibration

Each mass flow controller should be calibrated on an annual schedule. The mass flow controllers can be calibrated either electronically or manually. Manual calibration consists of adjusting the zero (no flow) and span potentiometers using a reference flow standard. The potentiometers can be accessed on the side of the flow controller housing. Electronic calibration can be performed by inserting the appropriate calibration constants into the advanced portion of the setup screen. Appendix A provides a worksheet to calculate these constants using a calibrated flow reference standard. Note that the canister mass flow controller calibration should be based on the average ambient sampling temperature as specified in the section on End Pressure under Programming the Model 2200.

Procedure for Calibrating the Canister Mass Flow Controller

If frequent pressure tolerance errors occur, either the pressure tolerance value entered in the Set-Up screen is set too low or the mass flow controller needs to be re-calibrated. The MFC is re-calibrated as follows:

1. Remove the top cover of the sampler
2. Disconnect the 1/8" stainless steel tubing at the inlet to the mass flow controller
3. Connect a calibrated flow standard to the inlet to the mass flow controller
IMPORTANT: Use a standard that will not contaminate the sampler components
4. Connect an evacuated canister to the canister fitting on the rear of the sampler
5. Enter the Set-Up Screen and advance to the Manual screen

6. Set the canister flow rate by touching FSet1 or FSet2 (the Model 2200-2 has two canister flow controllers) by using the keypad to enter the value normally used in sampling, usually 3.5 cc/min for a 24 hour sample.
7. Open the valve on the canister and activate the internal canister valve by checking Can1 or Can2 on the manual screen
8. Allow the flow to stabilize and record the flow rate shown in Flow1 or Flow2 on the manual screen along with the flow rate indicated by the flow standard. **IMPORTANT:** The flow rate shown on the manual screen is the raw value that is NOT corrected by the calibration constants entered in the Set-Up screen. The calibration factors are only applied to the flow rate shown on the main screen when the sampler is running.
9. Calculate the MFC calibration constants (slope and intercept) using the procedure contained in Appendix A.
10. Exit the manual screen and enter the Set-Up screen. Enter the canister MFC slope and intercept. Exit the Set-Up screen
11. Enter a schedule and observe the canister flow rate while the sampler is running. Compare this value to the flow standard to verify that the MFC is properly calibrated.
12. Remove the flow standard and re-connect the inlet tubing to the MFC and replace the top cover on the instrument.

Procedure for Calibrating the Cartridge Mass Flow Controller

The cartridge MFC is re-calibrated as follows:

1. Remove the Luer connector or cartridge on the channel to be calibrated
2. Connect a calibrated flow standard on the Luer fitting on the outlet tubing on the front panel of the sampler.

3. Enter the Manual screen
4. Set the cartridge flow rate by touching FSet3 or FSet4 (the Model 2200-2 has two cartridge flow controllers) by using the keypad to enter the value normally used in sampling.
5. Activate the vacuum pump by checking Car Pump (Pump 1).
6. Activate the internal cartridge valve by checking Cart1 or Cart2 on the manual screen
7. Allow the flow to stabilize and record the flow rate shown in Flow3 or Flow4 on the manual screen along with the flow rate indicated by the flow standard. **IMPORTANT:** The flow rate shown on the manual screen is the raw value that is NOT corrected by the calibration constants entered in the Set-Up screen. The calibration factors are only applied to the flow rate shown on the main screen when the sampler is running.
8. Calculate the MFC calibration constants (slope and intercept) using the procedure contained in Appendix A.
9. Exit the manual screen and enter the Set-Up screen. Enter the cartridge MFC slope and intercept. Exit the Set-Up screen
10. Disconnect the flow standard and attach a Luer connector between the inlet and outlet tubing on the front panel.
11. Enter a schedule and allow the sampler to start sampling.
12. Remove the Luer connector and reconnect the flow standard at the outlet Luer connector tubing on the channel that is being sampled.
13. Observe the cartridge flow rate while the sampler is running. Compare this value to the flow standard to verify that the MFC is properly calibrated.
14. Remove the flow standard.

Pressure Transducer Calibration

Pressure transducers should be calibrated on an annual schedule. The pressure transducers can be calibrated either electronically or manually. Since manual calibration requires removal of the transducer from the sampler, it is recommended that the pressure transducers be calibrated electronically. Appendix A provides a worksheet to calculate these constants using a calibrated pressure reference standard.

Model 2200 Parts List

Components of the Model 2200 are shown in the following Parts List. This list does not include common parts such as fuses, fittings, or fasteners.

Chassis	2200-100-1
Front Panel	2200-100-2
Rear Panel	2200-100-3
Canister Mass Flow Controller (0-20ccpm)	2200-200-1A
Carbonyl Mass Flow Controller (0-2 lpm)	2200-200-1B
3-Way Solenoid Valve	2200-200-2
Canister Tubing Set	2200-200-3
Cartridge Tubing Set	2200-200-4
Cartridge Filter Holder	2200-200-5
Cartridge Filter (47mm Teflon)	2200-200-6
Canister Filter Assembly	2200-200-7
Canister filter (7 micron)	2200-200-8
Pressure Transducer	2200-200-9
Ozone Scrubber Heater (Complete)	2200-200-10
Ozone scrubber (KI copper coil)	2200-200-11
Heater Relay	2200-300-1
Vacuum Pump	2200-200-12
Vacuum Pump Relay	2200-300-2
2-Way Solenoid Valve	2200-200-13
*Canister Pressure Pump	2200-200-14
*Pressure Gauge	2200-200-15
*Pressure Adjusting Valve	2200-200-16
Single Board Computer	2200-400-1
GPIO Board	2200-400-2
Interface Board	2200-400-3

PC Power Supply	2200-400-5
Temperature Probe	2200-400-4
Power Supply	2200-300-3
Cooling Fan	2200-300-4
Power Switch	2200-300-5
Fuse Holder	2200-300-6
Pump Fan Guard	2200-500-1
Cooling Fan Guard	2200-500-2
Vacuum Line Tubing Set	2200-200-16
Check Valve	2200-200-17
MFC Canister Ch.1 Cable	2200-700-1
MFC Canister Ch.2 Cable	2200-700-2
MFC Cartridge Ch.1 Cable	2200-700-3
MFC Cartridge Ch.2 Cable	2200-700-4
GPIO Cable Set	2200-700-5
*Canister Pump Relay	2200-300-2
*Canister Pump Relay Cable	2200-700-9
Vacuum Pump Relay Cable	2200-700-10

*Pressurized Canister Option

Appendix A – Procedures for Flowmeter and Pressure Transducer Calibration

Flowmeter Calibration Procedure—Canister Channel

1. Enter the **Manual** screen, observe the average flow controller flow rate (the flow rate will oscillate). If it is not 0.00 ± 0.02 , manually adjust the flow controller output by turning the "zero" adjust screw on the side of the flow controller.
2. Go to the **Advanced** screen and enter 0.00 for the intercept for the channel being calibrated.
3. Connect an accurate flowmeter (referenced to the desired temperature and pressure) to the canister inlet and connect an evacuated canister to the canister channel of the flow controller being calibrated. Open the valve on the canister.
4. Under **Manual** Mode, set the flow controller set point to its normally operating value, and open the channel solenoid valve. Read the flowmeter value from the screen (X) after the flow has stabilized. X:
5. Read the calibrated flow unit value (Y). Y:
6. Close the channel solenoid valve.
7. The slope is calculated by:

$$Slope = \frac{Y}{X}$$

Slope:

8. Go to the **Advanced** screen, enter the new value for the slope.
9. Go to the **Schedule** screen and program the sampler to start in a few minutes. After the sampler has started, verify that the flow rate displayed on the main screen is the same as the calibrated flow device. If the flow rates agree, then the channel has been calibrated correctly and the flow standard can be removed.

Flowmeter Calibration Procedure—Canister Channel with Pressurized Option

1. Enter the **Manual** screen and without the pump running, observe the average flow controller flow rate (the flow rate will oscillate). If it is not 0.00 ± 0.02 , manually adjust the flow controller output by turning the "zero" adjust screw on the side of the flow controller.
2. Go to the **Advanced** screen and enter 0.00 for the intercept for the channel being calibrated.
3. Connect an accurate flowmeter (referenced to the desired temperature and pressure) to the canister inlet for the channel of the flow controller being calibrated.
4. Under **Manual** Mode, set the flow controller set point to its normally operating value, open the channel solenoid valve, and turn on the pump. Read the flowmeter value from the screen (X) after the flow has stabilized.

X:

5. Read the calibrated flow unit value (Y).

Y:

6. The slope is calculated by:

$$\text{Slope} = \frac{Y}{X}$$

Slope:

7. Go to the **Advanced** screen, enter the new value for the slope.
8. Go to the **Schedule** screen and program the sampler to start in a few minutes. After the sampler has started, verify that the flow rate displayed on the main screen is the same as the calibrated flow device. If the flow rates agree, then the channel has been calibrated correctly and the flow standard can be removed.

Flowmeter Calibration Procedure—Cartridge Channel

1. Enter the **Manual** screen and without the pump running, observe the flow controller flow rate (the flow rate will vary). If it is not 0.00 ± 0.02 lpm, manually adjust the flow controller output by turning the "zero" adjust screw on the side of the flow controller.
2. Go to the **Advanced** screen and enter 0.00 for the intercept for the channel being calibrated.
3. Disconnect the Luer coupler on the front panel and connect an accurate flowmeter (referenced to the desired temperature and pressure) to the outlet tube of the channel being calibrated.
4. Under **Manual** Mode, set the flowmeter set point to its normally operating value, open the channel solenoid valve, and turn on the pump. Read the flowmeter value from the screen (X) after the flow has stabilized. **X:**

5. Read the calibrated flow unit value (Y). **Y:**

6. The slope is calculated by:

$$Slope = \frac{Y}{X}$$

Slope:

7. Go to the **Advanced** screen, enter the new value for the slope.
8. Go to the **Schedule** screen and program the sampler to start in a few minutes. After the sampler has started, verify that the flow rate displayed on the main screen is the same as the calibrated flow device. If the flow rates agree, then the channel has been calibrated correctly and the flow standard can be removed.

Pressure Transducer Calibration Procedure

1. For the pressure transducer to be calibrated, set the slope to **1.0** and the intercept to **0.0** in the Advanced option.
2. Attach an evacuated canister (absolute pressure < 0.05 psia) to the canister inlet.
3. Record the pressure and enter the negative of this value for the intercept (e.g. recorded value = -0.1, the intercept = +0.1) in the Advanced screen.
4. Disconnect the evacuated canister from the channel inlet.
5. Accurately determine the ambient pressure (P1) within ±0.05 psi.. **P1:**
6. Enter the main screen, and observe the average pressure (P2) displayed. **P2:**

7. The slope is calculated by:

$$Slope = \frac{P1}{P2}$$

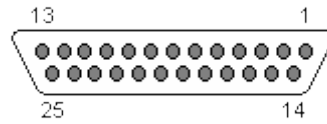
Slope:

8. Enter the slope value for the pressure transducer in the Advanced screen.
9. Repeat Step 6 to verify that the pressure displayed is the same as the atmospheric pressure (P1).
10. If the pressure is different by more than ±0.1 psi, enter **1.0** for the slope in the Advanced option and repeat Steps 5 to 10.

Appendix B – Schematics

Appendix C – Manual for Mass Flow Controller

Rear Panel Analog Outputs



Pin Number	Signal	Calibration*
1	Pressure 2	6.05 psia/volt
2	Open	
3	Pressure 1	6.05 psia/volt
4	Open	
5	Flow Rate 4	Range 4/5 volts
6	Open	
7	Flow Rate 3	Range 3/5 volts
8	Open	
9	Flow Rate 2	Range 2/5 volts
10	Open	
11	Flow Rate 1	Range 1/5 volts
12	Open	
13	Enclosure Temperature ²	14.7°C/volt
14	Ground	
15	Ground	
16	Ground	
17	Ground	
18	Ground	
19	Ground	
20	Ground	
21	Ground	
22	Ground	
23	Ground	
24	Ground	
25	Ground	

*Calibration constants must be applied to measured voltages to adjust to calibrated standards.

¹Scrubber temperature is present on sampler with carbonyl channels

²This temperature is present when sampler is configured in an outdoor enclosure.

³This signal is present in samplers configured with an inlet line flow meter which measures the inlet line pressure which is proportional to the inlet line flow rate.

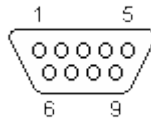
Trigger Sampling Option

If the triggered sampling option is installed, sampling can be initiated independently for each channel by a switch closure on the rear panel connector shown below. To use the trigger option, in **Schedules** or **SOP** the **Triggered Operation** check box must be selected for each channel to be triggered. When this check box is checked, the date and time inputs are ignored and only the duration value is used. When the sampler senses a connection between the trigger pins, the appropriate channel will start purging/sampling. Once sampling has started for a channel, the connection between the pins can be opened without stopping the sampling.

When a trigger is sensed, the following can occur:

- If neither channel is sampling or the system has already started purging, purging will start prior to sampling for the channel that is triggered. The duration of purging is specified in **Setup**.
- If the canister channel is already sampling and the cartridge channel is triggered, purging will start prior to sampling on the cartridge channel.
- If the cartridge channel is already sampling and the canister channel is triggered, the canister channel will start sampling immediately.

Rear Panel Trigger Inputs



Pin Number	Signal
1	Canister Channel 1 ¹
2	Cartridge Channel 1
3	Not used
4	Not used
5	Not used
6	Canister Channel 1
7	Cartridge Channel 1
8	Not used
9	Not used

¹If triggered operation has been selected, Canister Channel 1 will start when Pin 1 is shorted to Pin 6. Cartridge Channel 1 will start when Pin 2 is shorted to Pin 7.