

UCD IMPROVE Standard Operating Procedure #201

Sampler Maintenance by Site Operators

*Interagency Monitoring of Protected Visual Environments
Air Quality Research Center
University of California, Davis*

Version 3.3

Updated By: Josh Grant Date: 12/10/2018

Approved By: Yongjing Zhao Date: 01/18/2019



TABLE OF CONTENTS	
1. INTRODUCTION.....	5
1.1 IMPROVE NETWORK.....	5
1.2 IMPROVE AEROSOL SAMPLER OVERVIEW	5
2. IMPROVE Aerosol Sampling.....	6
2.1 SAMPLER SHELTERS	6
2.2 OPERATOR QUALIFICATIONS.....	7
2.3 INTERFERENCES.....	7
2.4 SAMPLING SUPPLIES	7
2.4.1 Collocated "X" Module Sampling.....	10
2.4.2 Special Studies	10
2.5 SCHEDULES	11
2.5.1 Sampling Schedule.....	11
2.5.2 Sample Change Schedule	11
2.5.3 Maintenance Schedule.....	11
3. IMPROVE Aerosol Sampler	11
3.1 SAMPLER CONTROLLER.....	12
3.1.1 Normal Mode.....	16
3.1.2 Changing Cartridge Mode.....	17
3.1.3 Diagnostic Mode.....	17
3.1.4 Initializing Mode	17
3.2 PM _{2.5} SAMPLING MODULES	17
3.2.1 PM _{2.5} Module Inlet and Cyclone.....	19
3.2.2 Critical Orifice Flow Control	20
3.2.3 PM _{2.5} Module Flow Rate Measurement.....	20
3.2.4 PM _{2.5} Module Filter Cassettes and Cartridges.....	21
3.3 PM ₁₀ SAMPLING MODULE.....	22
3.3.1 PM ₁₀ Module Inlet and Cyclone.....	22
3.3.2 PM ₁₀ Module Flow Rate Measurement.....	23
3.3.3 PM ₁₀ Module Filter Cassettes and Cartridges	23
4. SAMPLER INSTALLATION	23
5. TUESDAY SAMPLE CHANGES	24
5.1 PREPARATION.....	24
5.2 SAMPLE CHANGE PROCEDURES	25
6. TROUBLESHOOTING GUIDE	38
6.1 COMMON SAMPLER PROBLEMS	38
6.2 SAMPLER CONFIGURATION.....	40
APPENDIX I: ELEVATION FACTORS	47
APPENDIX II: MODULE DOOR QUICK REFERENCE SHEETS	48

LIST OF FIGURES

Figure 1-1. Photo of the IMPROVE aerosol sampling modules inside a shelter.....	7
Figure 2-1. Picture of a blue box showing the three filter bags.....	8
Figure 2-2. Picture of the contents of one re-sealable bag – supplies for one week of sampling.....	8
Figure 2-3. Sample cartridge for the 2B module (yellow sticker) with four cassettes. Only three of the cassettes contain sample filters (indicated by the three labels).....	9
Figure 2-4. Sampling calendar for November and December 2015 illustrating the repeating 3-week cycle.....	10
Figure 3-1. Standard IMPROVE aerosol sampler configuration.....	13
Figure 3-2. Controller module.....	13
Figure 3-3. Controller terminal.....	15
Figure 3-4. Current status, sampling is active.....	17
Figure 3-5. Current status, idle screen.....	17
Figure 3-6. Current status, sampling complete, filter change required.....	17
Figure 3-7. PM _{2.5} module from the Version II IMPROVE aerosol sampler.....	18
Figure 3-8. Flow Diagram For The IMPROVE PM _{2.5} Module.....	19
Figure 3-9. PM ₁₀ module from the Version II IMPROVE sampler.....	23
Figure 5-1. Field logsheet for sample cartridges with three cassettes (i.e., three sampling days).....	
Figure 5-2. Photos illustrating the removal of position 3 cassette (note black o-ring on removable cassette) from the cartridge.....	25
Figure 5-3. Home screen with filter readings button.....	27
Figure 5-4. Select operator initials screen.....	27
Figure 5-5. Start Exposed Filter Readings screen.....	27
Figure 5-6. Flow rate and pressure readings screen.....	28
Figure 5-7. Continue screen.....	28
Figure 5-8. Change filter screen.....	29
Figure 5-9. PM _{2.5} cassette orientation.....	29
Figure 5-10. PM ₁₀ cassette orientation.....	29
Figure 5-11. Active sampling Tuesday sample change.....	30
Figure 5-12. Verify movable filter position is installed.....	30
Figure 5-13. Clean (Initial) filter readings screen.....	32
Figure 5-14. Low flow through cyclone warning.....	32
Figure 5-15. Problem still detected.....	32
Figure 5-16. Lost Ebox connection error screen.....	33
Figure 5-17. Software connection error screen.....	34
Figure 5-18. Check sample logsheet values.....	35
Figure 5-19. Replace memory card screens.....	35
Figure 5-20. Memory card warning.....	35
Figure 5-21. Home screen with current status.....	36
Figure 5-22. Filter Readings interrupted.....	36
Figure 6-1. Low ET Warning.....	39
Figure 6-2. Settings Menu.....	41
Figure 6-3. Change date and time screen.....	41
Figure 6-4. Change Time Zone screen.....	41
Figure 6-5. Advanced Menu Password.....	42
Figure 6-6. Site Config screen.....	42
Figure 6-7. Shutdown screen.....	43
Figure 6-8. Edit Schedule screen.....	43

Figure 6-9. Maintenance Menu screen	44
Figure 6-10. Edit Module screen	44
Figure 6-11. Controller Part Number screen	45
Figure 6-12. Site Info screen	45
Figure 6-13. Help screen	46

LIST OF TABLES

Table 2-1. Types of cartridges for 1-in-3 day sampling.	9
Table AI-1. Elevation factors for a range of elevations. The elevations are listed in units of both meters (m) and feet (ft) above mean sea level. The pressure in units of millimeters of mercury is also listed for each elevation.	47

1. INTRODUCTION

1.1 IMPROVE Network

IMPROVE (Interagency Monitoring of Protected Visual Environments) is a cooperative program of the National Park Service, National Forest Service, Bureau of Land Management, Fish and Wildlife Service, Environmental Protection Agency, and state and tribal organizations. IMPROVE was established in 1985 to aid the creation of Federal and State implementations for the protection of visibility in Class I areas (156 national parks and wilderness areas) as stipulated in the 1977 amendments to the Clean Air Act.

The first IMPROVE samplers were deployed in 1988 at twenty sites. The number of sites has increased significantly over the years. For a current list of sites please visit:

<http://views.cira.colostate.edu/fed/DataWizard/Default.aspx>

Click on the “Sites” tab to see the site list. A map of the network is available here:

<http://views.cira.colostate.edu/fed/SiteBrowser/Default.aspx?sskeyse=10001&smmkeys=57>

Zoom out on the map to see sites beyond the Continental United States in Alaska, Hawaii, Virgin Islands, Canada, and South Korea. Click on any site to see photos and information about that site.

Every IMPROVE site employs an aerosol sampler to collect particulate matter samples below 2.5 μm ($\text{PM}_{2.5}$) and below 10 μm (PM_{10}). The Version 1 IMPROVE aerosol sampler was used in the network from 1988 to 2000. In 2000, the Version 2 IMPROVE aerosol sampler was introduced, and the sampling protocol changed from twice a week to every third day. The new schedule meant consistency with the EPA-designated schedule for the speciation trends network (STN), which operates in urban areas. The Version 3 controller and Eboxes were developed in 2010 through 2012 and 2013, but never made it to field deployment. The Version 4 IMPROVE sampler controller deployment started in 2016 and will be completed in 2019. The V4 controller and Eboxes have new digital I²C pressure sensors, touch screen interface, and internet capability for remote control and data transfer.

1.2 IMPROVE Aerosol Sampler Overview

A picture of an IMPROVE aerosol sampler is shown in Figure 1-1. The sampler consists of four modules used to collect aerosol samples, labeled 1A, 2B, 3C, and 4D. The third white box from the left, in the center of the picture is the controller. The controller contains the microcontroller with programmed schedule, the touchscreen, and other electronic equipment required to operate the sampler. Note that the four sampling modules have inlet pipes protruding from the top of them, while the controller does not. During a sampling period, each of the four modules collects a filter sample simultaneously. The four modules are used to collect four different types of samples.

- Module 1A collects PM_{2.5} particles on Teflon filters. These filters are analyzed by four methods at UC Davis:
 - a. gravimetric analysis for PM_{2.5} mass
 - b. hybrid-integrating plate and sphere (HIPS) for optical absorption
 - c. x-ray fluorescence (XRF) for elements: sodium (Na) to lead (Pb)
 - d. Fourier Transform Infrared (FTIR) spectroscopy can be used for black carbons (BC) and organic carbons (OR)
- Module 2B collects PM_{2.5} particles on nylon filters. A denuder before the nylon filter removes nitric acid and sulfur dioxide vapors. These filters are analyzed by ion chromatography for nitrate, chloride, sulfate and nitrite by Research Triangle Institute (RTI).
- Module 3C collects PM_{2.5} particles on quartz filters. These filters are analyzed for organic and elemental carbon using Thermal Optical Reflectance (TOR) in house at UC Davis or by Desert Research Institute (DRI).
- Module 4D collects PM₁₀ particles on Teflon. These filters are analyzed by gravimetric analysis for PM₁₀ mass at UC Davis.

Figure 1-1. Photo of the IMPROVE aerosol sampling modules inside a shelter.



2. IMPROVE Aerosol Sampling

2.1 Sampler Shelters

The sampling modules are protected from direct sunlight by a shelter. The shelter will also protect the operator and filters during sample changes in rain or snow. The shelter will vary

from an outdoor stand with a sunshield to a fully enclosed but well-ventilated shelter. The shelters at IMPROVE sites should not be heated or air-conditioned.

2.2 Operator Qualifications

A UC Davis technician will train the site operator. The operator must pay attention to details, perform the work in a timely manner, and communicate any problems to UC Davis. The operator should have a general familiarity with electrical connections, flow through pipes, and of the pumps for the IMPROVE sampler.

2.3 Interferences

The IMPROVE network is designed to measure regional air quality. Therefore, the sites are located in remote areas. The sites should not be heavily influenced by local sources. If a new activity begins close to the site (if you can see or smell emissions when you are at the site), please inform UC Davis of the possible interference at once. Examples of activities that might influence the air quality samples are:

- Fires
- Road or building construction
- Gas or diesel powered generator
- Increased traffic
- Mining operations or timber harvesting

The IMPROVE siting criteria are detailed in *UCD IMPROVE SOP #126: Site Selection*.

The quality of the samples is dependent upon careful handling of the samples. Careless handling of the samples can lead to contamination.

- Do not leave the samples sitting out in the open air for longer than a few minutes.
- Do not touch the surfaces of the filters.
- Be careful not to drop the samples.
- Ship the used samples back to UC Davis as soon as possible.
- Protect the samples from water contamination when changing samples in the rain or snow.
- Store the samples at room temperature (i.e., do not leave the samples in a hot car, or in the sun).

2.4 Sampling Supplies

The laboratory at UC Davis prepares the sample cartridges for the IMPROVE sites. Every three weeks, UC Davis sends a “Blue Box” containing the necessary sampling supplies to each site (Figure 2-1). Usually, there will be two Blue Boxes at a site, one box in current use and the

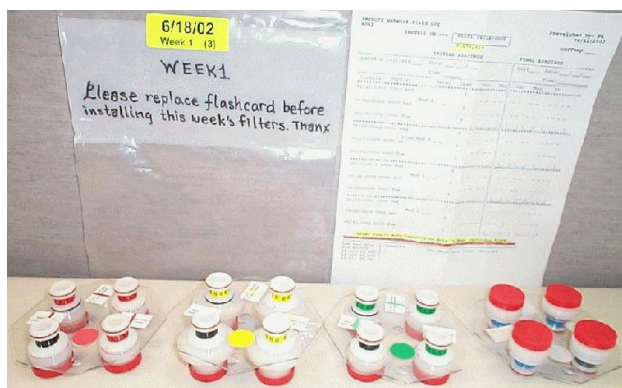
second box ready for the next period or ready to be shipped back to UC Davis. Inside each Blue Box are three re-sealable bags and an SD memory card for storing the electronic sampling data. Each bag contains the supplies for one week (Figure 2-2): four sample cartridges, one for each of the four modules, and the corresponding logsheet. The cassettes are color-coded for each module: red for module 1A, yellow for module 2B, green for module 3C, and blue for module 4D. A sampler which has a fifth module will use orange for module 5X. All cassettes are capped to protect the filters, and the red caps must be removed before the cassettes are installed in the modules. Each re-sealable bag is labeled with the date that the cartridges inside the bag are to be installed. The Blue Box will be labeled with the three sample install dates.

The Blue Box should be received 5 calendar days before the first sample-change day. If the appropriate box is not present before the change date, the operator should contact the UCD laboratory (530-752-1123). Once all the filter samples in a Blue Box have been used, the Blue Box should be shipped back to UCD by UPS, FedEx, or USPS services. UC Davis provides shipping labels to most sites for returning the Blue Box.

Figure 2-1. Picture of a blue box showing the three filter bags.



Figure 2-2. Picture of the contents of one re-sealable bag – supplies for one week of sampling.



The filter samples are loaded into cassettes to form an airtight seal around each filter, and the cassettes are loaded into cartridges to allow sequential samples to be collected without operator intervention. Figure 2-3 is a picture of a sample cartridge and four cassettes. Each cartridge contains three or four cassettes, but only two or three of the cassettes contain sample filters since only two or three samples are collected in any given week. Table 2-1 lists the three cartridge configurations used for routine sampling. The unused cassettes contain pieces of paper or blank filters (blank filters do not require any special procedures of the operator). Figure 2-4 shows a sampling calendar for September and October, 2015 to illustrate the 3-week repeating cycle.

Figure 2-3. Sample cartridge for the 2B module (yellow sticker) with four cassettes. Only three of the cassettes contain sample filters (indicated by the three labels).




Table 2-1. Types of cartridges for 1-in-3 day sampling.


Cartridge Type	Cassette 1	Cassette 2	Cassette 3	Cassette 4
Type 1	Thursday	Sunday	Unused or field blank	Unused
Type 2	Wednesday	Saturday	Tuesday	Unused
Type 3	Friday	Monday	Empty hole	Unused


Figure 2-4. Sampling calendar for November and December 2015 illustrating the repeating 3-week cycle.

September 2015							Cartridge Type
Tue	Wed	Thu	Fri	Sat	Sun	Mon	
1	2	3	4	5	6	7	1
8	9	10	11	12	13	14	2
15	16	17	18	19	20	21	3
22	23	24	25	26	27	28	1
29	30						2
October 2015							
Tue	Wed	Thu	Fri	Sat	Sun	Mon	
		1	2	3	4	5	2 continued
6	7	8	9	10	11	12	3
13	14	15	16	17	18	19	1
20	21	22	23	24	25	26	2
27	28	29	30	31			3

KEY

 Sample change day

 Sample collection day

 Sample change and collection day

2.4.1 Collocated “X” Module Sampling

Collocated (or duplicate) sampling is performed at a small number of sites. At these sites, five sampling modules are operated. The fifth module is a duplicate of one of the other four modules and is labeled as the “5X” module.

2.4.2 Special Studies

At times, special aerosol studies will be performed at some of the sites. These studies may require additional sampling equipment and supplies. The individual site operators will be contacted before any special studies are initiated at their sites.

2.5 Schedules

2.5.1 Sampling Schedule

IMPROVE filter samples are collected every three days on the EPA-designated schedule. The samples are collected over 24 hours, starting at midnight, according to the local standard time.

2.5.2 Sample Change Schedule

The sample cartridges should be changed every Tuesday as described in Section 5. If the operator cannot change the samples on Tuesday, contact UC Davis (530-752-1123) for instructions on when to change the samples. Alternative days for sample changes are shown on the IMPROVE calendar and vary each week. It takes approximately fifteen minutes to change the sample cartridges every Tuesday. For two of every three Tuesday sample changes, the sampler will not be actively collecting samples. For one of every three Tuesday sample changes, the sampler will be actively collecting samples and the sampling will be interrupted to change the filter cartridges. The procedures required to change the cartridges on sampling days are slightly more complicated than on the non-sampling days.

2.5.3 Maintenance Schedule

A maintenance crew from UC Davis will visit the site every other year to perform routine maintenance. The routine maintenance consists of:

- Cleaning and refurbishing the sampler
- Replacing parts when necessary
- Making scheduled modifications to the sampler and controller program
- Checking the existing calibrations of the sample modules
- Re-calibrating the flow rates of the sample modules
- Discussing procedures with the site operator
- Providing training for any site operators

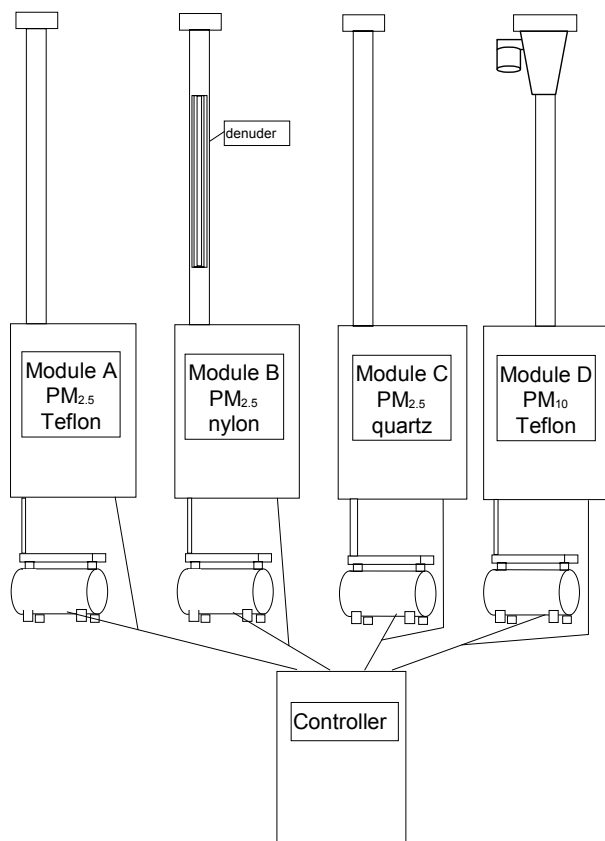
3. IMPROVE Aerosol Sampler

The standard IMPROVE aerosol sampler configuration is shown in Figure 3-1. Most sites will have four modules plus a controller as shown in the figure. Each module has a dedicated pump. At steady state each pump requires 3.3 amperes at 120 volts. The 1A, 2B, and 3C modules collect PM_{2.5} samples. The 1A and 3C modules are identical except that their flow rates are calibrated for different types of filters (as described in Section 1.2). The 2B module has a slightly different cartridge holder configuration to accommodate the larger diameter filters that are used in the 2B module. The 4D module collects PM₁₀ samples and has a very different

configuration to accommodate a PM₁₀ cyclone; the most noticeable operational difference is that the sample cartridges must be installed in an opposite orientation compared to the other modules.

Selected sites will have a fifth module used to perform sampling for quality assurance purposes. The fifth module will be a duplicate of one of the other modules and will be referred to as a 5X module.

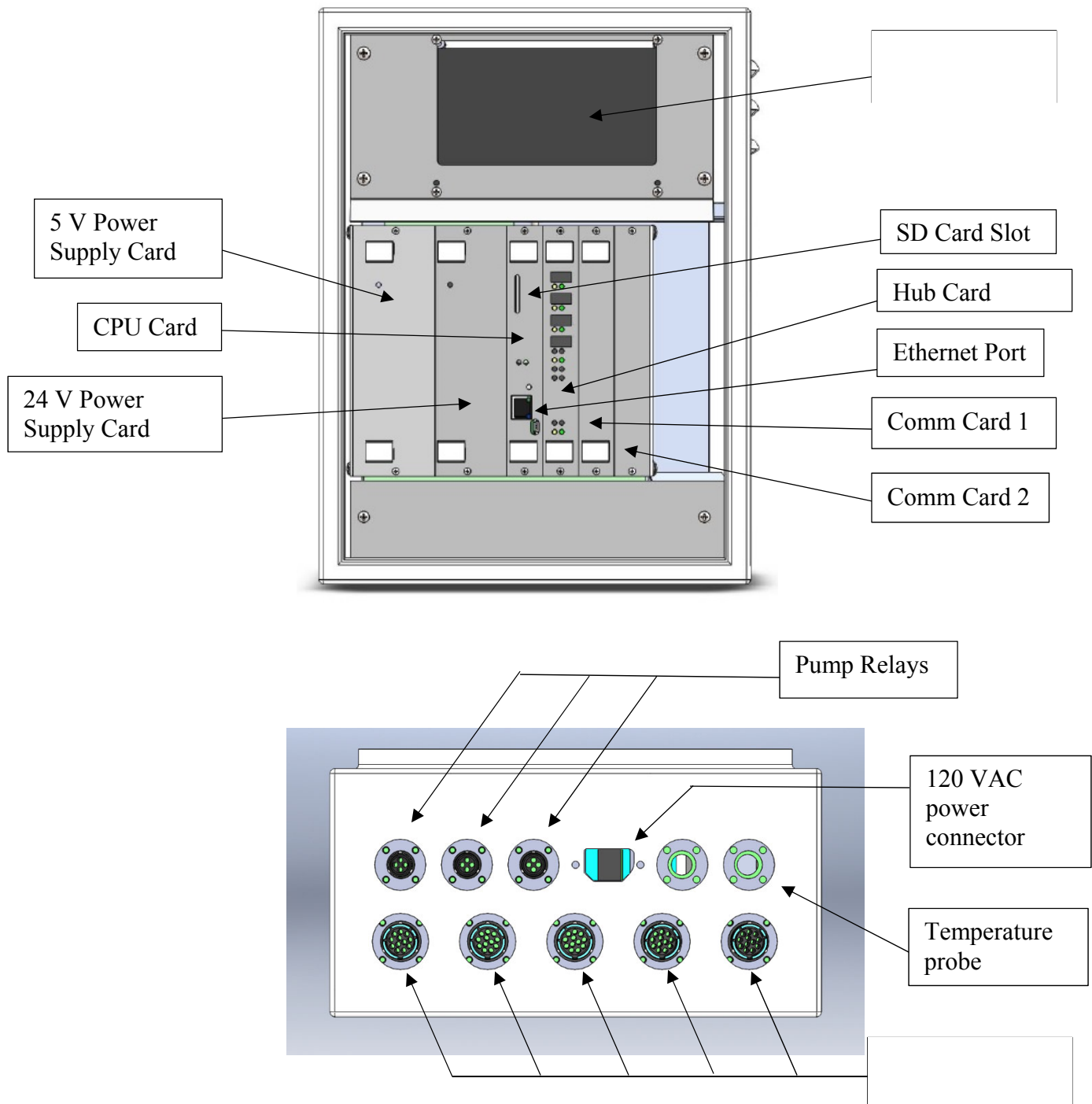
Figure 3-1. Standard IMPROVE aerosol sampler configuration.



3.1 Sampler Controller

The sampler controller is used to control the sample collection and acquire data during sampling. The Version 4 controller consists of a Beaglebone Black Rev C microcontroller, an LCD touchscreen, plus appropriate electronic components. The controller is shown in Figure 3-2. The lower portion of the figure shows the connectors on the bottom of the controller. The controller can currently accommodate up to five filter sampling modules.

Figure 3-2. Controller module.



The controller performs the following functions:

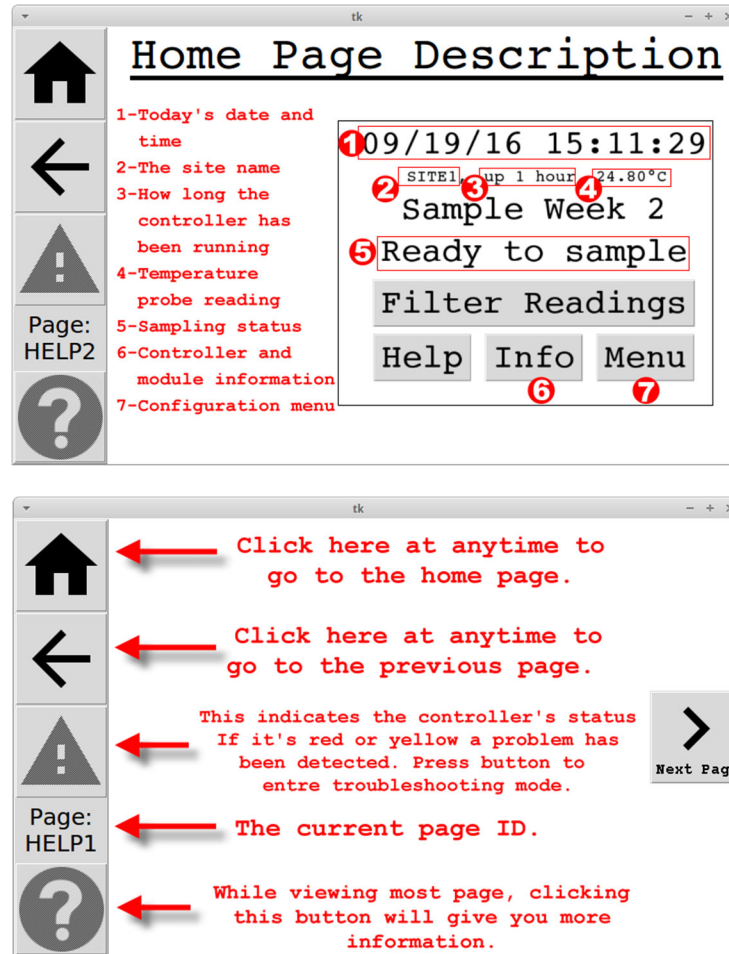
- Provides a status of current sampler operations to the site operator.
- Provides an interface for recording initial and final measurements of the flow rate through each filter during sample changes to the site operator.
- Provides options for configuring sampling protocols of the site and filter types of each module. This is normally performed by a UC Davis technician at the time of installation.
- Keeps the current date and time.
- Switches the filter solenoids and pump relays on and off.
- Records pressure transducers measurements. A standard configuration has 8 transducers, two in each module. Measurement is done once a second and averages are recorded on the flash card every 15 minutes.
- Records ambient temperature measurements. This is on the same schedule as that of the pressure transducers.
- Records the solenoid valve number that is open.
- Download all the measurements to the removable SD memory card.
- Communicate over a network to send and receive data remotely.

The control program is written and compiled at UC Davis in Linux/Python on a personal computer. The program is flashed onto the microcontroller. More detailed instructions will be provided to the site operator(s) if a software upgrade is ever necessary.

Fifteen-minute average temperature and pressure transducer measurements are stored on a removable SD memory card. The SD card is replaced every three weeks. Most sites with a Version 4 controller will send data back to UC Davis over a network. The used card is sent back to UC Davis and the data are uploaded to a database only if a network is unavailable. The SD card has the capacity to store more than three weeks of sampling data if necessary, and will act as a backup in case the network fails or data are lost.

The Home Screen is shown in greater detail in Figure 3-3. The LCD touchscreen is used to navigate the menu with user friendly buttons and instructions. These are pointed out in the figure. In many cases, the LCD will list the available options for navigation.

Figure 3-3. Controller terminal.



The controller program has 4 modes: Normal Mode, Diagnostic Mode, Changing Cartridge Mode, and Initializing Mode. The program is generally in Normal Mode whether the sampler is running or not. In the Normal Mode, the sampler may require a sample change or be ready to sample. Section 3.1.1 through 3.1.4 details the controller modes.

To move from the Normal Mode to the Changing Cartridge Mode, press the **Filter Readings** button from the Home Screen. This will switch the display from the Home Screen to the Filter Readings Mode. After completing the standard filter change, the program will automatically return to the Normal Mode. For other menus, press the **Menu** button and navigate through the different menu options. Certain menu options will take the controller into Diagnostic Mode, which is programmed to time out after 15 minutes. Initializing Mode is not relevant for operators and is only accessed while the controller is booting up.

3.1.1 Normal Mode

When the sampler is in Normal Mode, the sampler may be ready to sample, currently sampling, or locked, which means a filter change is needed before it can sample again. The Home Screen display shows whether the sampler is sampling, ready to sample, or if a filter change is needed. In the figures below, several example displays are shown.

In the first example, Figure 3-4, the first line displays the current date and time. For this example, the date is October 19, 2017. The time is 3:52 pm or 15:52. The second line indicates that the 5 digit site code is ABCD9, it has been turned on for 1 hour, and the temperature is -1.00°C. The third line indicates which filter bag week number is currently installed. The fourth line indicates what the sampler is currently doing, which is running or sampling.

Figure 3-5 shows that the sampler is idle. It is not a sampling day, but it is ready to sample when the next sampling day begins.

The status screen in Figure 3-6 indicates that the sampler has collected all the samples for the week and will not sample until the operator changes the cartridges and collects the exposed and clean filter readings.

Figure 3-4. Current status, sampling is active.

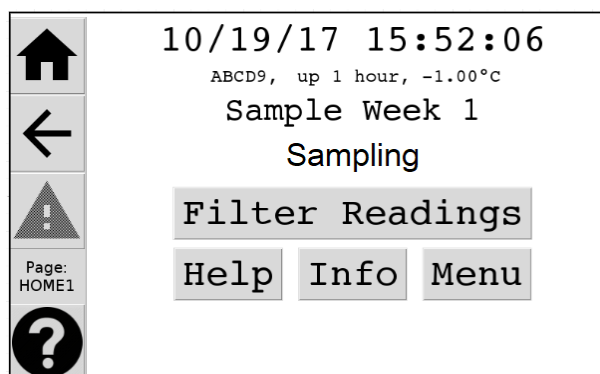


Figure 3-5. Current status, idle screen.

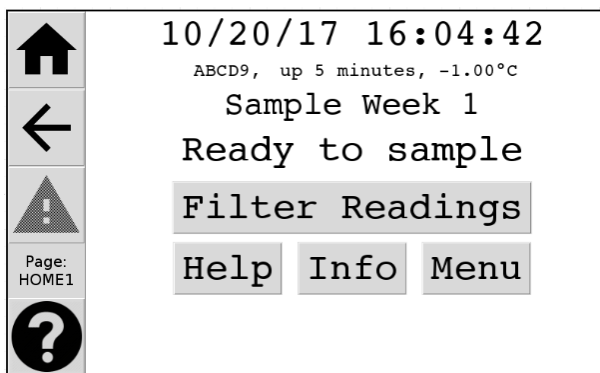
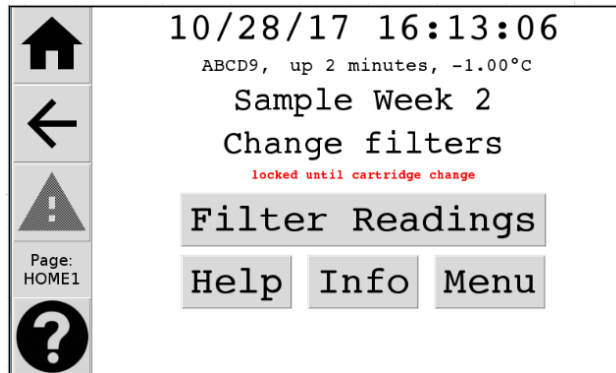


Figure 3-6. Current status, sampling complete, filter change required.



3.1.2 Changing Cartridge Mode

The Changing Cartridge mode is accessed by pushing the **Start** button after the **Filter Readings** option has been pressed from the Home Screen. Once in Changing Cartridge mode, filter readings must be completed before it returns to Normal Mode. This is the only mode that will not time out into another mode. This is because double sampling a filter will invalidate it and it is preferable for the controller to not sample rather than to double sample. A controller stuck in Changing Cartridges mode will not sample correctly. Operator should verify that current status when leaving site is either, “Sampling,” or, “Ready to Sample,” (Figure 3-4 and Figure 3-5).

3.1.3 Diagnostic Mode

Diagnostic mode is a mode mainly used for maintenance purposes. This mode is designed to interrupt normal sampling for purposes such as sampler maintenance, equipment replacement and testing, and other advanced purposes. This mode will automatically time out after a certain amount of time if it is entered.

3.1.4 Initializing Mode

Boot mode is the mode the controller must go through during the initial power up and software loading sequence. This mode is only accessed during controller restarts and power ups.

3.2 PM_{2.5} Sampling Modules

The inside of an IMPROVE aerosol sampler PM_{2.5} module is shown in Figure 3-7. The flow diagram for the IMPROVE PM_{2.5} module is shown in Figure 3-8. Approximate pressure readings in units of inches of mercury are listed in the figure.

Figure 3-7. PM_{2.5} module from the IMPROVE aerosol sampler.

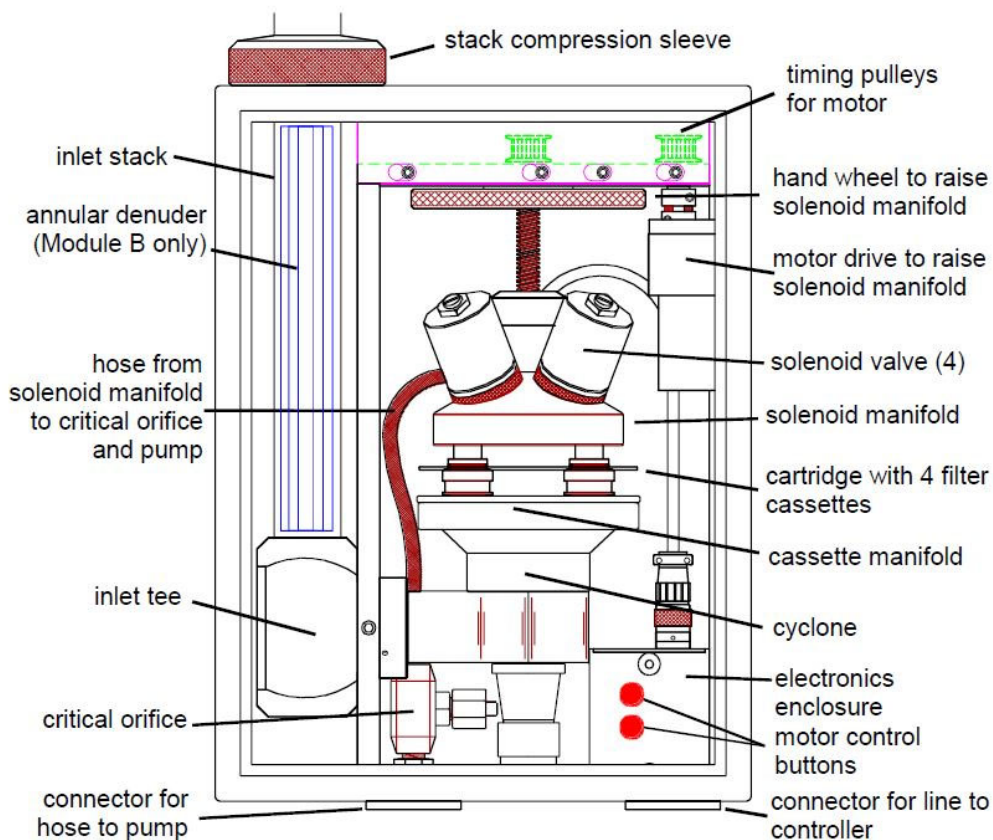
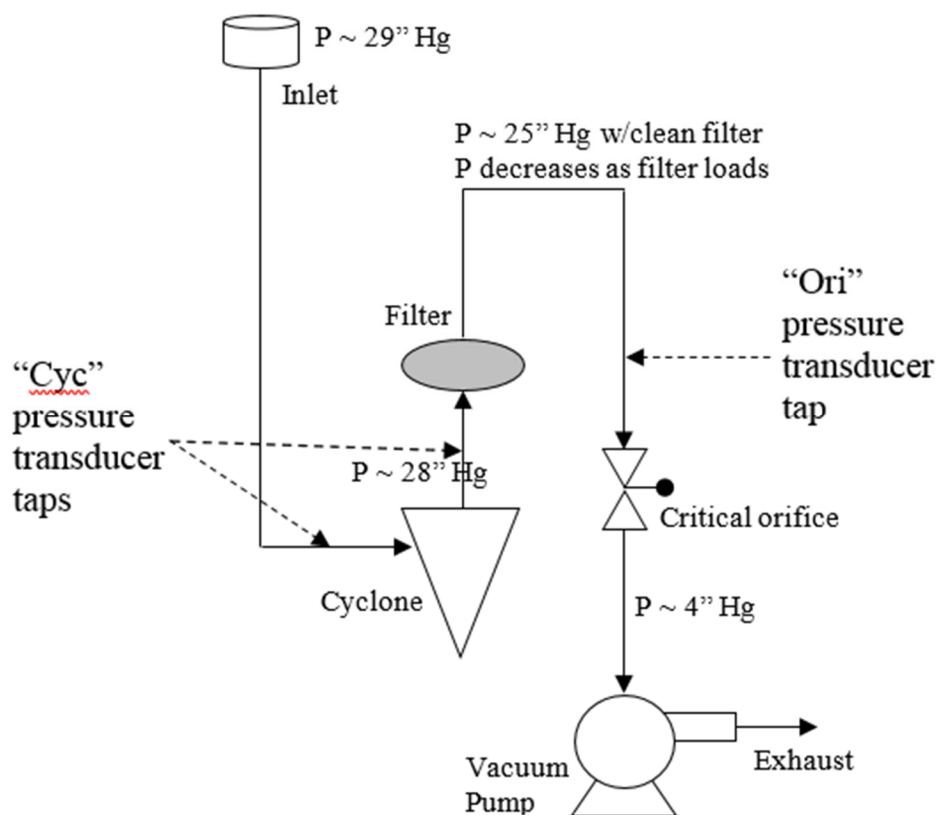


Figure 3-8. Flow diagram for IMPROVE PM_{2.5} module.



3.2.1 PM_{2.5} Module Inlet and Cyclone

The ambient air enters through a screened inlet on top of the stack. The screen removes bugs, rain, and particles larger than approximately $15 \mu\text{m}$. The air stream then passes through a cyclone that removes particles larger than $2.5 \mu\text{m}$. The cyclone is located inside the module, as shown in Figure 3-. The cyclone is 50% efficient at removing particles with aerodynamic diameters larger than $2.5 \mu\text{m}$ at the nominal flow rate of 22.8 L/min . A 5% decrease in flow rate, from 22.8 to 21.7 L/min , increases the cut point to $2.9 \mu\text{m}$.

Module 2B (nylon) has a carbonate-coated annular denuder to remove nitric acid (HNO_3) and sulfur dioxide (SO_2). The denuder consists of four concentric 61-cm aluminum tubes. The calculated efficiency for removing HNO_3 is greater than 99.7%. The denuder is located inside the inlet tube of module 2B.

A temperature probe is inserted in the inlet of one of the three PM_{2.5} modules (typically module 3C but it doesn't matter). The temperature probe is situated in the air stream just prior to the cyclone. The temperature is measured every minute and the average temperature is recorded on the SD memory card every 15 minutes.

3.2.2 Critical Orifice Flow Control

A critical orifice located between the filter and the vacuum pump shields the flow system from pump fluctuations and resultant flow rate fluctuations. Critical flow will be maintained as long as the pressure behind the orifice is 53% or less of the pressure upstream of the orifice (behind the filter). A properly operating pump will maintain critical flow under most conditions. Critical flow will be lost when a pump begins to fail or, more commonly, when the filter loading is heavy (i.e., if the air is much polluted). Heavy filter loadings cause large pressure drops across the filter which result in the pressure in front of the critical orifice being too low to maintain critical flow.

A needle valve serves as the critical orifice in the IMPROVE PM_{2.5} aerosol samplers. The valve is adjusted by an authorized technician during each annual maintenance visit to achieve the desired nominal flowrate. A machined 0.062" ruby orifice serves as the critical orifice in the IMPROVE PM₁₀ aerosol samplers, with the needle valve serving to fine tune the flow rate.

A constant volumetric flow rate of 22.8 L/min must be maintained to keep a 2.5 µm cut point. Two factors can cause the flow rate to vary from the nominal: a change in pressure drop across the filter or a change in ambient temperature. Each of these factors varies throughout the course of every sampling period, the pressure drop due to gradual loading of the filter with particles and the temperature due to natural variability. Although flow rates vary by less than 1 L/min during a typical 24-hour period due to temperature fluctuations, they sometimes vary more, especially when a filter begins to clog. The critical orifice does not protect against these flow variations; its only purpose is to dampen pump fluctuations.

3.2.3 PM_{2.5} Module Flow Rate Measurement

The sample flow rate is monitored using pressure transducers. The controller will read and record the transducer measurements every second and record the averages every 15 minutes. The transducer measurements are calibrated for flow rate using an orifice flow check device that has been calibrated to a primary flow standard at UC Davis.

The flow rate determined by cyclone pressure drop is the primary measurement used for the air quality data and is referred to as the "CYC" flow rate. The "CYC" flow rate is related to the pressure drop of air as it passes through the cyclone. The two pressure transducer ports used to measure the pressure drop are placed in the inlet tee and immediately after the cyclone. The cyclone approximates a venturi-type meter. The flow rate equation is expressed in terms of parameters determined during the flow rate calibration at the site. The equation also includes a pressure function based on the elevation of the site, $F(\text{elev})$, and a temperature function based on the average ambient temperature during sample collection. The elevation factor is 1.00 for sites near sea level and increases to 1.20 at 10,000 feet, as listed in Appendix I: Elevation factors. The temperature function is equal to 1.00 at 20°C and varies from 0.95 at -9°C (17°F) to 1.05 at 50°C (122°F). The equation for flow rate based on the first set of transducers is

$$Q_m = 10^a M^b * F(\text{elev}) \sqrt{\frac{T + 273}{293}},$$

where

Q_m = actual volumetric flow rate (L/min) from the “CYC” reading,

M = “CYC” reading on the controller screen,

$F(\text{elev})$ = the pressure function based on the elevation of the site (see Appendix I),

T = average ambient temperature during sampling (°C), and

a and b = universal calibration constants

The flow rate can also be determined by the orifice pressure and is referred to as the “ORI” flow. But “ORI” flow is not used for PM_{2.5} modules. The “ORI” flow rate is related to the air pressure immediately before the critical orifice. IMPROVE does not use the ORI flow rate equation for PM_{2.5}. The equation for flow rate based on the second transducer is

$$Q_v = (c - d * V) * (F(\text{elev}))^2 \sqrt{\frac{T + 273}{293}},$$

where

Q_v = actual volumetric flow rate (L/min) from the “ORI” reading,

V = “ORI” reading on the controller screen,

$F(\text{elev})$ = the pressure function based on the elevation of the site,

T = average ambient temperature during sampling (°C), and

c and d = universal calibration constants.

3.2.4 PM_{2.5} Module Filter Cassettes and Cartridges

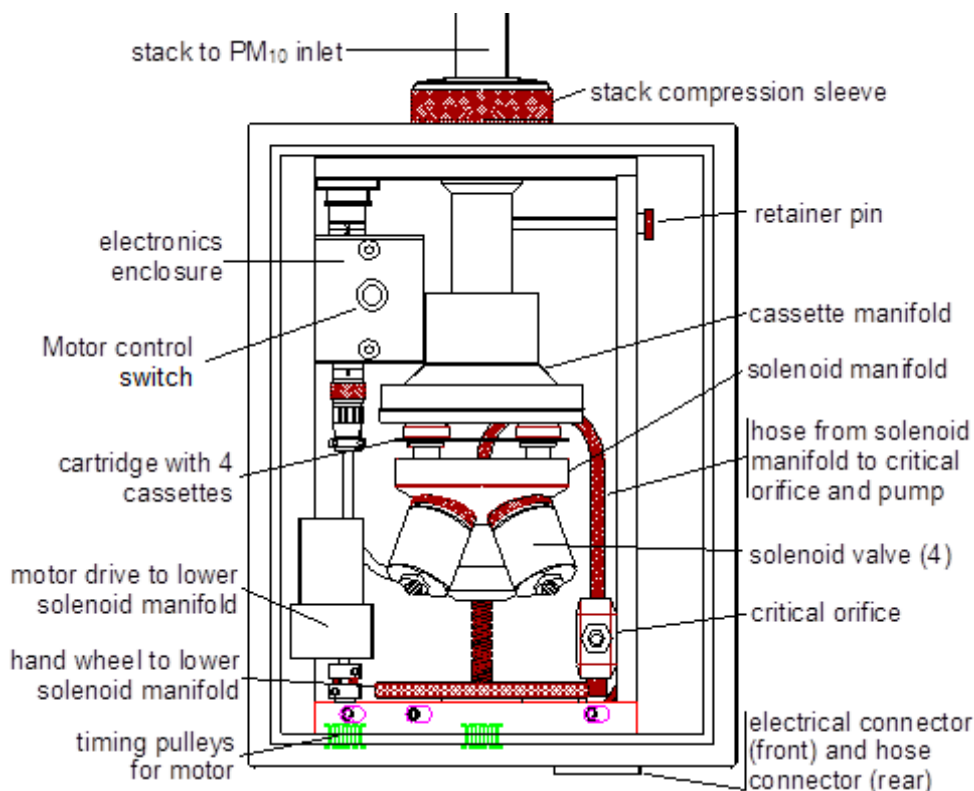
The filter cassettes and cartridges are manufactured specifically for the IMPROVE sampler. They are made of acetal homopolymer with stainless steel screens. The two halves of the cassette snap together and are sealed with an o-ring. A special tool is required to separate and assemble the two halves. This process is only done at the UC Davis central laboratory when the filters are unloaded and reloaded. The individual cassettes are always installed in cartridges, with four cassettes per cartridge. Most cassettes are secured in the cartridges by a snap ring and cannot be removed easily. Some cassettes are to be moved from one cartridge and to a second cartridge in the field; these cassettes are held in by an o-ring and can be removed and inserted relatively easily. Each cartridge has a center hole and a small alignment hole. When the cartridge is placed on the cyclone manifold, alignment pins on the manifold prevent the cartridge from being rotated a quarter or half turn. Each cassette is labeled with the site, module, and the sample collection date. When

the cartridges are loaded into the PM_{2.5} modules, the labels on the cartridges will always be oriented facing upward.

3.3 PM₁₀ Sampling Module

An IMPROVE PM₁₀ module is shown in Figure 3-9. Note that the PM₁₀ module manifold is oriented in the opposite direction as the PM_{2.5} module manifold.

Figure 3-9. PM₁₀ module from the IMPROVE sampler.



3.3.1 PM₁₀ Module Inlet and Cyclone

The ambient air enters through an inlet on top of the stack. Two different inlets have been used in the IMPROVE network. The first inlet was manufactured by Wedding TP10 and uses cyclonic flow to eliminate particles larger than 10 μm from the sample stream. The Wedding inlet requires a flow rate of 19 LPM. The second inlet is manufactured by Sierra-Anderson and uses impaction to eliminate particles larger than 10 μm from the sample stream. The Sierra-Anderson inlet is the only inlet currently used in the IMPROVE network. The Sierra-Anderson inlet requires a flow rate of 16.9 LPM. Both inlets are 50% efficient at removing particles with aerodynamic diameters larger than 10 μm at the respective nominal flow rates.

3.3.2 PM₁₀ Module Flow Rate Measurement

The sample flow rate is monitored using orifice pressure transducers. The controller will read and record the transducer measurements every minute and record the averages every 15 minutes. The transducer measurements are calibrated for flow rate using an orifice flow check device that has been calibrated to a primary flow standard at UC Davis. One flow measurement is made in the PM₁₀ module.

The flow rate is referred to as the “ORI” measurement. The “ORI” flow rate is related to the pressure before the orifice. The flow rate equation is expressed in terms of parameters determined during the flow rate calibration at the site. The equation also includes a pressure function based on the elevation of the site, F(elev), and a temperature function based on the average ambient temperature during sample collection, as described in Section 3.2.3. The equation for flow rate based on the second set of transducers is

$$Q_v = (c - d * V) * (F(\text{elev}))^2 \sqrt{\frac{T + 273}{293}},$$

where

Q_v = actual volumetric flow rate (L/min) from the “ORI” reading,

V = “ORI” reading on the controller screen,

$F(\text{elev})$ = the pressure function based on the elevation of the site (see Appendix I),

T = average ambient temperature during sampling (°C), and

c and d = universal calibration constants.

3.3.3 PM₁₀ Module Filter Cassettes and Cartridges

The same cassettes and cartridges are used in the PM₁₀ module as the PM_{2.5} modules, which were described in Section 3.2.4. The only difference is that they are inserted in an opposite direction compared to those in the PM_{2.5}. For the PM₁₀ module (4D), the labels and blue dot on the cartridge will be oriented facing **down** when they are installed in the sampler.

4. SAMPLER INSTALLATION

Prior to the installation of an IMPROVE sampler, the local support agency must establish power and erect a shelter at the site to prepare for installation of the sampler. UC Davis will provide the power requirements and shelter dimensions. UC Davis will ship the sampler to the site. A field technician from UC Davis will install the sampler. The installation consists of:

- Placing the controller and filter modules on a wall of the shelter and cutting holes in the ceiling for the inlets

- Installing the module inlets
- Connecting the cables between the controller, filter modules, and pumps
- Connecting the vacuum hoses between the modules and the pumps
- Selecting the sampling parameters
- Adjusting the flow rates of the sample modules
- Attaching the sample changing instructions to the inside of the controller door
- Training the site operators
- Installing the initial set of sample cartridges with the site operators

5. TUESDAY SAMPLE CHANGES

The sample cartridges should be changed every Tuesday. Alternative days for sample changes are shown on the IMPROVE calendar and vary each week. It takes approximately fifteen minutes to change the sample cartridges every Tuesday. Care must be taken during the change to protect the samples from contamination by rain or snow.

5.1 Preparation

The Blue Box should be received 5 calendar days before the first sample-change day. If the appropriate box is not present the Thursday before the sample-change date, the operator should contact the UCD laboratory (530-752-1123).

Before going to the site, the operator must check the dates on the Blue Box(es). The operator needs the Blue Box(es) with the bags for both the current install date and the previous install date. For example, if the first date on the new Blue Box is today's date, the operator should bring both this Blue Box and the previous Blue Box. The used samples are returned to the previous Blue Box, and the new samples are installed from the new Blue Box.

Figure 5-1. Field logsheet for sample cartridges with three cassettes (i.e., three sampling days).

UC Code: 2610		INSTALL ON --> BRID1 10/23/2018		FC# 2610.05.02				
IMPROVE Network Field Log								
INITIAL READINGS			FINAL READINGS					
Operator Initials: <u>TP</u>		Sampler's Date: <u>10/25/18</u>		Init <u>TP</u> Sampler's Date: <u>10/31/18</u>				
Sampler's Time: <u>13:37</u>				Sampler's Temp: <u>5°</u>				
				Sampler's Time: <u>14:30</u>				
SamDate	Day	Mod/Vec	Cass	Orl/Pressure	Cyc/Flow	Orl/Pressure	Cyc/Flow	ET
10/26/2018	Fri	Mod 1A <u>1.43</u>	1	<u>10.2</u>	<u>19.9</u>	<u>10.1</u>	<u>19.4</u>	<u>1435</u>
10/29/2018	Mon		2	<u>10.2</u>	<u>19.8</u>	<u>10.1</u>	<u>19.4</u>	<u>1435</u>
10/23/2018	Tue		3	<u>(9.5)</u>	<u>(18.2)</u>	<u>9.7</u>	<u>18.7</u>	<u>1433</u>
10/26/2018	Fri	Mod 2B <u>0.60</u>	1	<u>9.4</u>	<u>19.4</u>	<u>9.4</u>	<u>19.4</u>	<u>1435</u>
10/29/2018	Mon		2	<u>9.5</u>	<u>19.6</u>	<u>9.4</u>	<u>19.5</u>	<u>1435</u>
10/23/2018	Tue		3	<u>(9.4)</u>	<u>(19.6)</u>	<u>9.4</u>	<u>19.5</u>	<u>1433</u>
10/26/2018	Fri	Mod 3C <u>0.81</u>	1	<u>9.4</u>	<u>19.4</u>	<u>9.3</u>	<u>19.3</u>	<u>1435</u>
10/29/2018	Mon		2	<u>9.4</u>	<u>19.6</u>	<u>9.4</u>	<u>19.3</u>	<u>1435</u>
10/23/2018	Tue		3	<u>(9.4)</u>	<u>(19.7)</u>	<u>9.4</u>	<u>19.4</u>	<u>1433</u>
10/26/2018	Fri	Mod 4D <u>1.56</u>	1	<u>8.0</u>	<u>2.7</u>	<u>7.9</u>	<u>2.6</u>	<u>1435</u>
10/29/2018	Mon		2	<u>8.0</u>	<u>2.7</u>	<u>7.9</u>	<u>2.7</u>	<u>1435</u>
10/23/2018	Tue		3	<u>(7.6)</u>	<u>(2.7)</u>	<u>7.6</u>	<u>2.7</u>	<u>1433</u>
Always Orient each Cartridge Plate as per Instructions on each Door								
Lab Use Only		Comments		For Help Call (530) 752-1123				
1A 97.080 97.397	4D 94.181 93.675	Slash pile burning < 1 Km. from site. Probably drift smoke.						

Two of the three logsheets in every Blue Box will have three sampling days listed, while one of the three logsheets will only have two sampling days listed.

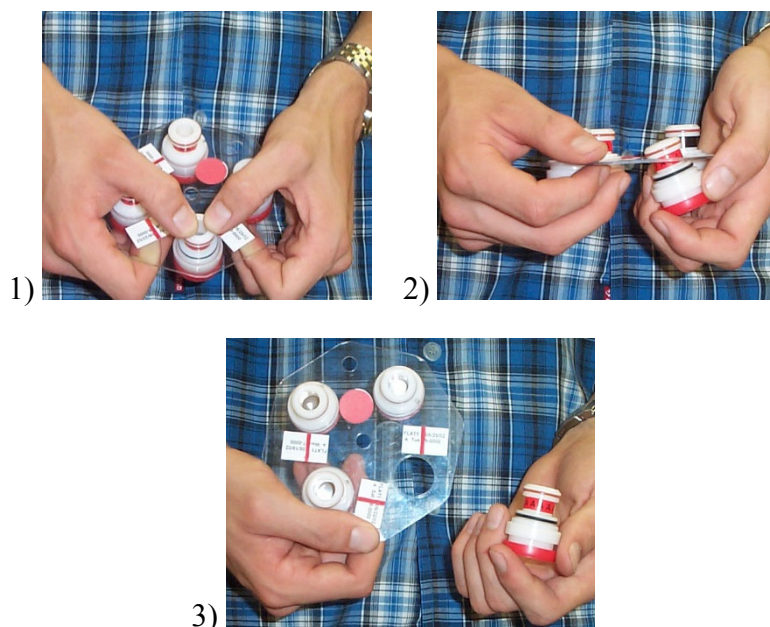
5.2 Sample Change Procedures

The basic steps in the sample change procedures are: 1) collect the exposed (final) filter flow rate readings for each used cassette; 2) remove the exposed filter cartridges; 3) install the clean cartridges; 4) collect the clean (initial) filter flow rate readings for each new cassette. This procedure must be repeated for all four sampling modules: 1A, 2B, 3C, and 4D.

For two of every three Tuesday sample changes, the modules will not be actively collecting samples. For one of every three Tuesday sample changes, the modules will be actively collecting samples, and the sampling will have to be interrupted to change the filter cartridges. The procedures required to change the cartridges on sampling days are slightly more complicated than on the non-sampling days.

On the active sampling days, the operator will have to transfer the cassettes in position 3, which are in the midst of sampling, from the old to the new cartridges. This transfer must be done for each of the four modules because all four modules are sampling simultaneously. The position 3 cassettes have a black O-ring around them and are the only ones that can be removed without a special tool. Figure 5-2 shows the removal of the position 3 cassette from a cartridge. This cassette must be loaded into the open hole in position 3 of the new cartridge. After the cassette is transferred to the new cartridge, the new cartridge is installed in the sampler. After the initial readings are taken, the sampler will resume collection on the filters in position 3. If the roof does not provide adequate protection from the elements, you should remove all four of the exposed cartridges, move to a protected location, switch the position 3 cassettes from the old cartridges to the new, and then return to the sampler to install the new cartridges.

Figure 5-2. Photos illustrating the removal of position 3 cassette (note black o-ring on removable cassette) from the cartridge.



The sample change procedures are detailed below. There will be a series of informational screens providing detail about what is happening throughout this procedure when the pumps are turned on or when the readings are being recorded on the memory card. The display will automatically switch to the next screen after several seconds.

1. Open the controller module door.
2. Fill in your initials, the date, and the time on the logsheet (Figure 5-1).
3. Make sure that the date and time on the controller module are correct. If they are off by more than 5 minutes, note the problem on the logsheet and refer to Section 6.3 to enter the correct date and time. If this is a sampling day, do not change the time and wait until the following week to correct the time.

4. Also, note any unusual activities that occurred during sampling days on the logsheet (e.g., fires, road paving, power outage, etc.)
5. Initiate the sample change sequence by pressing the **Filter Readings** button (Figure 5-3).
6. Press the set of initials corresponding to the operator performing the filter readings. If the operator's initials are not displayed, enter the initials by pressing the **Add Initials** button, then use the ↑ and ↓ to toggle value and the ← and → buttons to toggle position. Press **Save** to save and exit Add Initials screen (Figure 5-4).
7. Press start to begin recording filter readings (Figure 5-5). A status bar will explain what is happening during the procedure. Operators should listen for any pumps that fail to start, start slowly, or sound different from the other pumps. High pitched screeching; loud, hammer-like knocking; or electrical buzzing may indicate a serious problem and should be reported as soon as possible. If you encounter any of these issues, press “Yes” for troubleshooting. Otherwise, press “No” to continue to the readings.

Figure 5-3. Home screen with filter readings button.

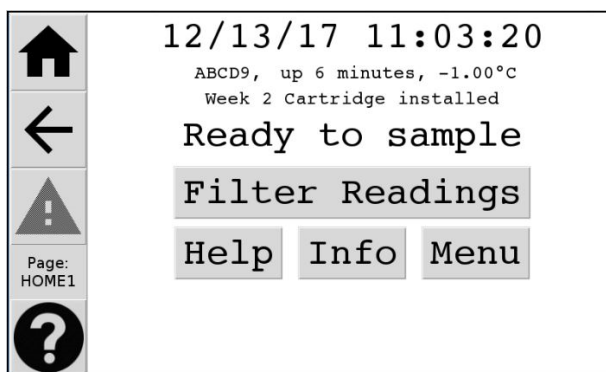


Figure 5-4. Select operator initials screen.

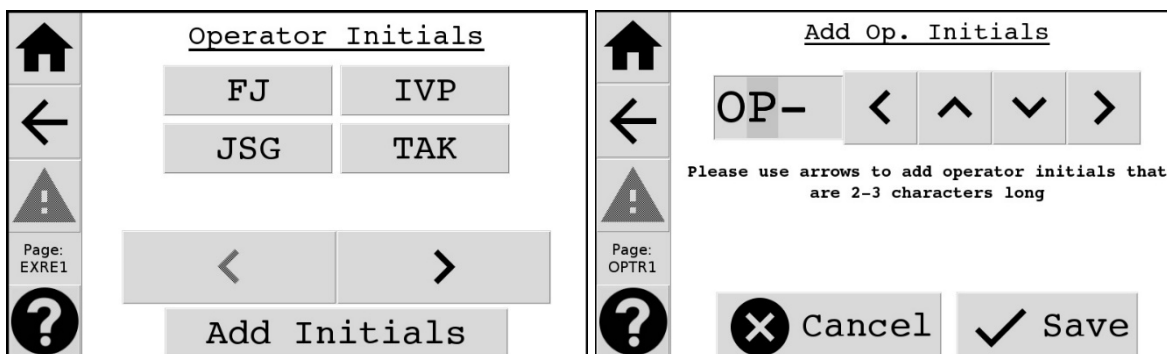










Figure 5-5. Start Exposed Filter Readings screen.

   Page: EXRE2 	<p><u>Exposed Filter Reading</u></p> <ul style="list-style-type: none"> ◆ Get Week 2 Logsheet dated 11/06/18 ◆ After pressing start, note any pumps that sound abnormal or louder than the others. ◆ When you are ready press "Start". <p>Start</p>
   Page: EXRE2 	<p><u>Exposed Filter Reading</u></p> <p>Readings finished.</p> <p>Did any pumps fail to start, start slowly, or sound abnormal?</p> <p>Yes No</p> <p><i>Press yes for troubleshooting.</i></p>

- Record the Exposed (Final) Readings (Pres/Ori, Flow/Cyc, and ET) for each used cassette. Figure 5-6 shows the flow and pressure readings (**Pres/Ori & Flow/Cyc**) and elapsed time (**ET**) for the first cassette (**FIL 1**) in Module 1A.
- Press the → key to go to the next module (and the ← key to move to the previous module). A standard sampler will have 8 or 12 filters (2 or 3 per module, depending on the week).
- When all the Exposed (Final) Readings are collected, check that all blank fields on the log sheet are filled in.
- Note any problems or mistakes made during the sample change procedures (e.g., dropped cartridge or cassette, touched filter with finger, etc.).
- Also note any unusual events that occurred near the site (e.g., fires, construction, painting, power outages, lightning strikes, fireworks, high traffic, etc.).
- If all the readings are acceptable, press the **Continue** button (Figure 5-7). To review any of the readings, navigate back using the arrow buttons.
- Put the completed logsheet in its original re-sealable bag (i.e., the re-sealable bag and the top of the logsheet should be labeled with the same date).
- Get out the new bag of filters labeled with the “**USE WEEK**” date displayed on the controller. Figure 5-8 shows that the bag label for the week is 11/27/18. For newer and backup operators, the **Instructions** button will walk through the procedure with written instructions and pictures.
- Press the **Filter Change Completed** when you have removed the exposed filters and installed the appropriate bag of clean filters (Figure 5-8).

Figure 5-6. Flow rate and pressure readings screen.

Sample date	Pres	Flow	ET
11/22/18	13.6	23.0	1435
11/25/18	13.6	23.0	1435

* Record these values on your log sheet.

Figure 5-7. Continue screen.

Sample date	Pres	Flow	ET
11/22/18	11.4	16.9	1435
11/25/18	11.4	16.9	1435

* Record these values on your log sheet.

Continue

17. Start with Module 1A, which is color-coded red.

If this is not a sampling Tuesday, the sampler should not be running when you arrive at the site.

- a1. Figure 5-8 shows the screen that will be displayed on a non-sampling Tuesday.
- b1. Remove the cartridge of used cassettes from the module by raising the sampling manifold using the stainless steel toggle switch and pulling out the cartridge.
- c1. Put the red caps on the cassettes and return the used cartridge to its original re-sealable bag.
- d1. Remove the red caps from the new cassettes and install the new cartridge in the module. Align the new cartridge in the lower manifold with the pins through the holes in the cartridge.
- e1. Lower the manifold using the stainless steel toggle switch (stop pressing the toggle switch when the motor starts to strain).

- f1. For the PM_{2.5} modules (1A, 2B, and 3C), the labels and the red, yellow, or green dot will be facing up (Figure 5-9). For the PM₁₀ module (4D), the labels and the blue dot will be facing down (Figure 5-10).

Figure 5-8. Change filter screen.

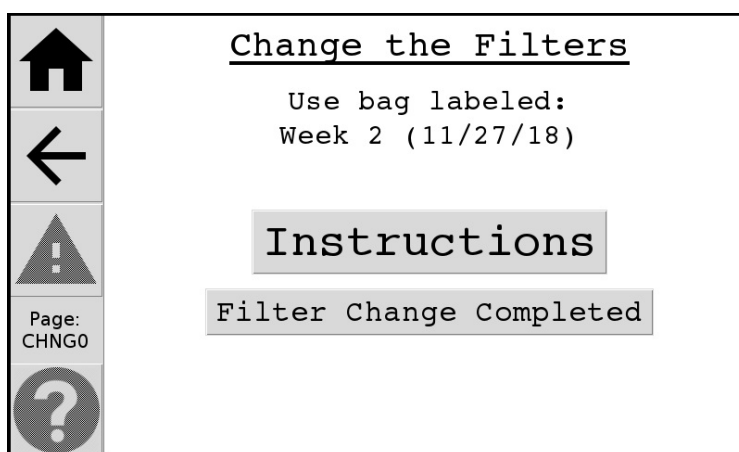


Figure 5-9. PM_{2.5} cassette orientation.

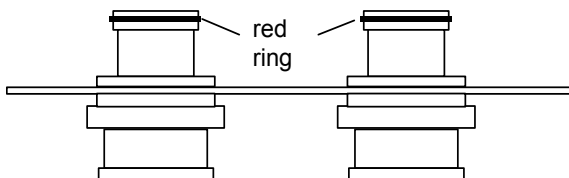
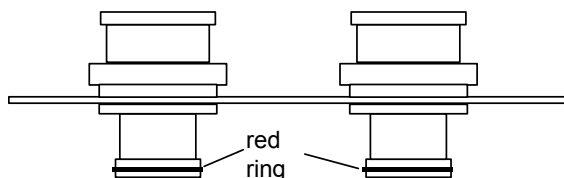


Figure 5-10. PM₁₀ cassette orientation.



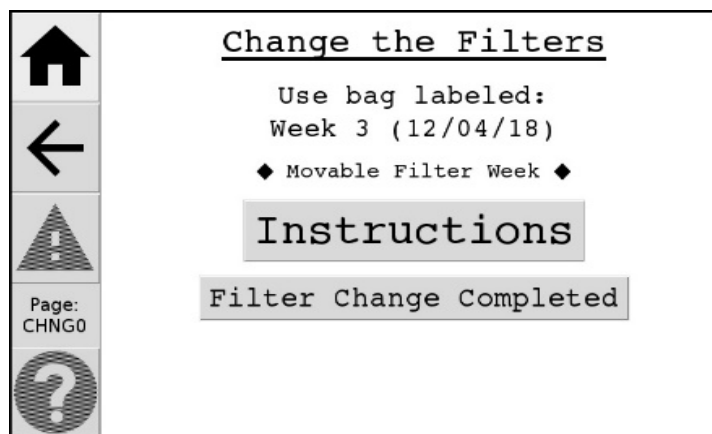
----- OR -----

If this is a sampling Tuesday, the sampler should be running when you arrive at the site.

- a2. **Figure 5-**Figure 5-11 shows the screen that will be displayed on a sampling Tuesday. Note the comment informing of “Movable Filter Week.”

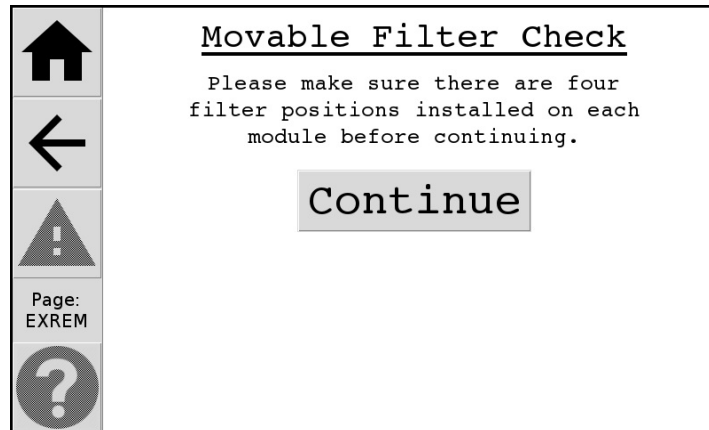
- b2. The old cartridge will have a black O-ring around the cassette in position 3, and the new cartridge will have an empty space in position 3.
- c2. Remove the used cartridge from the sampler by raising the sampling manifold using the stainless steel toggle switch and pulling out the cartridge.
- d2. Move the position 3 cassette of the used cartridge to the empty position in the new cartridge. (Do not move the cassette label from the old cartridge to the new cartridge.)
- e2. Install the new cartridge in the module — align the new cartridge in the lower manifold with the pins through the holes in the cartridge, and lower the manifold using the toggle switch.
- f2. Put the red caps on the used cassettes, and return the cartridge to its original re-sealable bag.
- g2. For the PM_{2.5} modules (1A, 2B, and 3C), the stickers and the red, yellow, or green dot will be oriented upwards. For the PM₁₀ module (4D), the labels and the blue dot will be facing down (Figure 5-10).

Figure 5-11. Active sampling Tuesday sample change.



- 18. Repeat Step 17 for modules 2B (yellow), 3C (green), and 4D (blue), making sure to install the appropriately colored cartridge in each module.
- 19. Press the **Filter Change Completed** button when all the new cartridges are installed. A reminder screen will ask the operator to verify that the movable position has been transferred from the old cartridge to the new one (Figure 5-12). Double check that four filters are present in each module and press **Continue**.

Figure 5-12. Verify movable filter position is installed.



20. The screen shown in Figure 5-13 shows the Clean (Initial) Readings for the new filters for all three filter cassette positions in Module 1A.
21. Record the Initial Readings (MxOri, Pres/Ori, and Flow/Cyc) for each new cassette on the new logsheet. Note that only one MxOri reading is necessary for each module, and only one space is provided on the logsheet for each module. **Several error screens may be encountered during the initial readings.**

Error Screen 1: If the flow rate through the cyclone is significantly less than the nominal flow rate, the message shown in Figure 5-14 will appear. There are three common reasons for this error. First, the cassette manifold was not lowered into place. Lower the manifold down using the motor toggle switch until the motor sounds strained. Then press the **Retest** button. Second, a cassette may be missing from the cartridge. Every third week, when the sample change day coincides with the sampling day, the current filter must be moved from the old cartridge to the new cartridge. This message will appear if the cassette was not transferred. Third, if the cartridge is installed upside down, the message in Figure 5-14 will appear. Re-install the cartridge in the correct direction, as shown on the diagram on the module door, and press the **Retest** button. If this corrects the problem, the screen shown in Figure 5-13 will appear. In all cases, correct the problem and press the **Retest** button. If you see the screen shown in Figure 5-15, the problem may not have been corrected. If the installation appears to be correct, it is possible to override this check and proceed with the sample change by pressing the **Force full test** button. If a warning cannot be resolved, pressing the **Skip** button will skip over the readings for the problem module. Please call UC Davis at (530) 752-1123 for assistance.

Figure 5-13. Clean (Initial) filter readings screen.

 Page: CLRE2 	<div style="text-align: center;"> <h2 style="margin: 0;">Module 1A</h2> <p style="margin: 5px 0;">11/27/18 10:18 Week 2</p> <table style="margin: 10px auto; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Sample date</th> <th style="text-align: left;">Vac (MxOri)</th> <th style="text-align: left;">Pres</th> <th style="text-align: left;">Flow</th> </tr> </thead> <tbody> <tr> <td>11/28/18</td> <td>1.04</td> <td>13.6</td> <td>23.0</td> </tr> <tr> <td>12/01/18</td> <td></td> <td>13.6</td> <td>23.1</td> </tr> <tr> <td>12/04/18</td> <td></td> <td>13.6</td> <td>23.0</td> </tr> </tbody> </table> <p style="margin-top: 10px;">* Record these values on your log sheet.</p> </div>	Sample date	Vac (MxOri)	Pres	Flow	11/28/18	1.04	13.6	23.0	12/01/18		13.6	23.1	12/04/18		13.6	23.0
Sample date	Vac (MxOri)	Pres	Flow														
11/28/18	1.04	13.6	23.0														
12/01/18		13.6	23.1														
12/04/18		13.6	23.0														

Figure 5-14. Low flow through cyclone warning.

 Page: LOWPR 	<div style="text-align: center;"> <h2 style="margin: 0;">Low Pressure Error</h2> <p style="margin: 5px 0;">Low pressure error detected. The filters maybe installed incorrectly. Please note that D-module filters are installed differently than A,B and C modules.</p> <p style="margin: 5px 0;">Press "?" button, on the left, to see pictures of properly installed filters.</p> <p style="margin: 5px 0;">If the filters were properly installed, please call us at (530) 752-1123 ASAP.</p> </div> <div style="text-align: center; margin-top: 20px;"> Retest </div>
--------------------------------	---

Figure 5-15. Problem still detected.

 Page: LOWPR 	<div style="text-align: center;"> <h2 style="margin: 0;">Low Pressure Error</h2> <p style="margin: 5px 0;">Low pressure error detected. The filters maybe installed incorrectly. Please note that D-module filters are installed differently than A,B and C modules.</p> <p style="margin: 5px 0;">Press "?" button, on the left, to see pictures of properly installed filters.</p> <p style="margin: 5px 0;">If the filters were properly installed, please call us at (530) 752-1123 ASAP.</p> </div> <div style="text-align: center; margin-top: 20px;"> Force full test Skip </div>
--------------------------------	---

Error Screen 2: If there is a problem during filter readings causing a lack of connection for more than 6 seconds, the screen shown in Figure 5-16 will be shown. This may indicate a problem with the controller connector board, module cable, or Ebox during filter readings. Inspect all connections looking for improperly seated module cable connections, and along each module cable looking for fraying, nicks, or rodent damage. If the problem has been solved, press the **Retry** button to retake Filter Readings. If no connection problem is obvious, inspect the LEDs on the face of the Ebox. A blinking green LED indicates proper functioning. A blinking red LED may indicate a restart is necessary. Troubleshooting can be done by unplugging the Ebox from either the Ebox side or controller side first. If this doesn't fix the problem, press the **Restart** button, then go through the Filter Readings procedure again.

Error Screen 3: If the software running in the background crashes during Filter Readings, the error screen shown in Figure 5-17 will be displayed. The controller will most likely reset itself within a minute. If it does not reset, pull the gray power cord from underneath the controller. Wait until the blue LED lights on the front panel of the controller stop blinking, then plug the gray power cable back in. If this problem persists, please call UC Davis at (530) 752-1123 for assistance.

Figure 5-16. Lost Ebox connection error screen

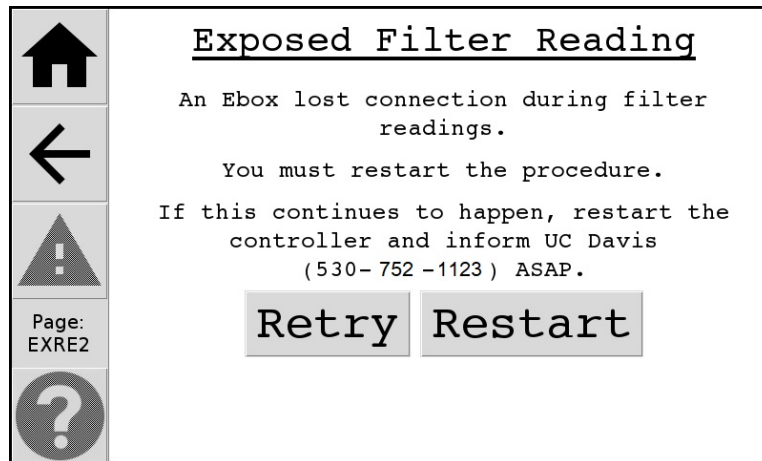
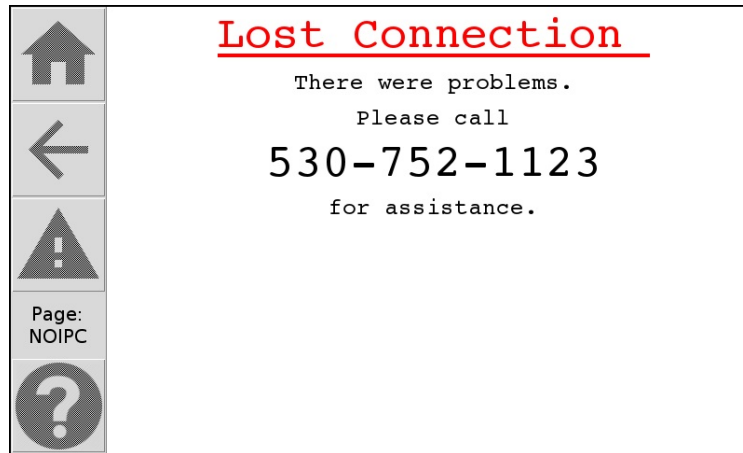


Figure 5-17. Software connection error screen.



22. The screen shown in Figure 5-18 will be displayed after Initial Readings are completed. Compare the filled out logsheet to the sample logsheet posted near the controller. Usually this sample logsheet will be on the outside of the 3C module door, though its location is site dependent. If the readings are out of the tolerances displayed on the sample logsheet, press **Yes** for troubleshooting options and the opportunity to retake Filter Readings.
23. If today's bag is the first in a new Blue Box, the controller will prompt the operator to change the SD memory card (Figure 5-18). Otherwise, skip to step 24.
 - a. Remove the flash card from the controller by pressing it down and removing finger, then pulling it out of the controller. Press the **Card Removed** button.
 - b. Place the memory card in the small plastic case in the old Blue Box.
 - c. Remove the SD memory card from the new Blue Box and place it in the controller. It will only fit in one way, with the 45° notch on the lower side of the card, and the electrical pins facing left. (If there is no memory card in the new box, reinsert the old one in the controller and write a note in the old logsheet.)
 - d. Press the **Card Inserted** button.

Note: If the warning shown in Figure 5-14 appears when a memory card is installed in the controller, try removing the SD card, and reinstalling it. Then press the **Back** button. If the warning is still displayed, install the old memory card and note the problem on the logsheet or call UC Davis (530) 752-1123. Then press the **Skip** button.

Figure 5-18. Check sample logsheet values.

Check logsheet

Please compare logsheet
against sample logsheet.
Are any of the values out of range?
Press yes for troubleshooting.

Yes No

Page: CLRE3

Figure 5-19. Replace memory card screens.

Change Flashcard

Please remove the SD card.

Instructions

Card Removed

Page: FSHRM

Change Flashcard

Please insert new SD card.

Instructions

Card Inserted

Page: FSHCH

Figure 5-20. Memory card warning.

Flashcard check

SD card initialization failed

status: device not mounted
state: SdcardState.ERROR

Back Skip

Page: CLRE4

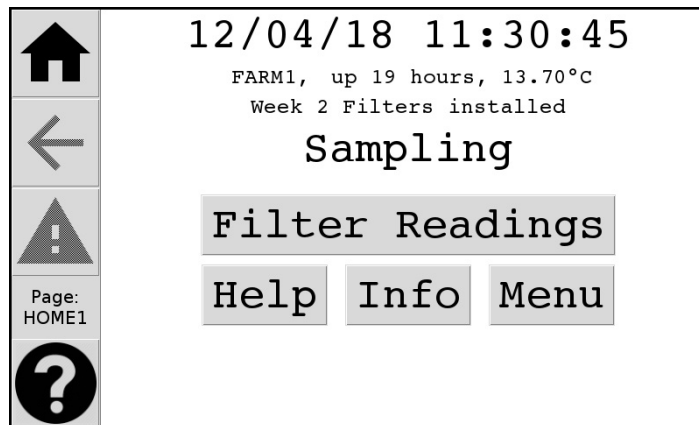
24. The information for the Filter Readings will now be recorded on the flash card, and a series of messages (“Checking SD card...”) will indicate the status. Then, the sampler will return to the Home screen, and a current status screen will be displayed.

- a. If this is not an active sampling day, the sampler remains off. The sensors will be read and the Home screen with the current status, “Ready for Sampling,” will automatically appear.

----- OR -----

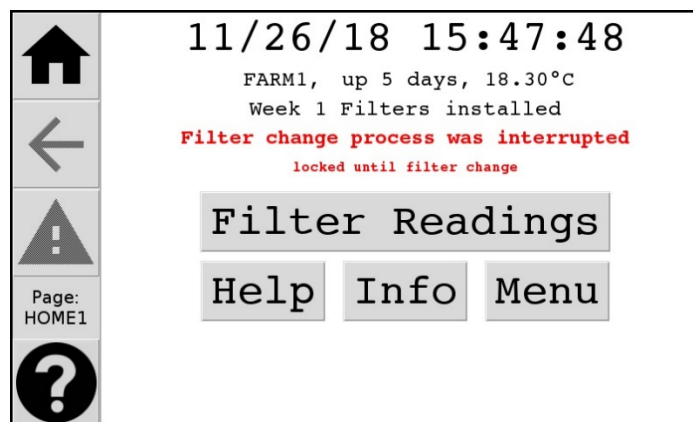
- b. If this is a sampling Tuesday, the sampler will resume sampling on Filter 3. The Home Screen will be displayed with a current status screen similar to Figure 5-21.

Figure 5-21. Home screen with current status.



25. Make certain that a current status is showing on the screen before you leave. If the operator sees a status similar to the one shown in Figure 5-22, Filter Readings may need to be taken again.

Figure 5-22. Filter Readings interrupted.



26. Close the doors of the modules.

27. If you have any problems during a sample change, contact UC Davis at (530) 752-1123.
28. If this is the last (third) bag of samples in the Blue Box, return the box to UC Davis as soon as possible. Simply adhere the mailing UPS/U.S.P.S. label (found stapled to the Week 3 logsheet) to the Blue Box and send the box through the UPS/USPS.

6. TROUBLESHOOTING GUIDE

When a problem is identified with the sampler, first note the issue on the logsheet. Contact the UC Davis sample handling laboratory or field shop to diagnose the problem at (530) 752-1123, (e-mail improvehelpdesk@ucdavis.edu). If possible, call from the site to facilitate troubleshooting and prevent the loss of samples.

6.1 Common Sampler Problems

6.1.1 *Missed Tuesday sample change.*

- a. If there are remaining sampling days in the week, remove the exposed filters as would normally be done and put in the clean filters that were to have been installed on the last change day. Make a note on the logsheet.
- b. If the week is completely missed, remove the exposed filters as normal but do not put in the filters for the missed week (keep the missed samples in the shipping box). Install the cartridges labeled for the current week. On the logsheet for the unused cartridges, note that they were not used and the reason for not using them.

6.1.2 *The display is blank.*

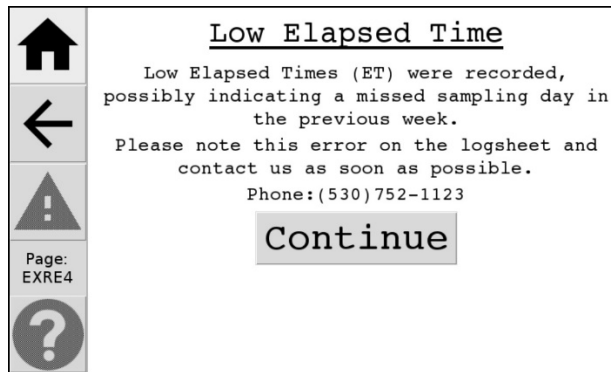
- a. Power may be off.
 - i. Check the main circuit breaker; turn it off and on if you are unsure if it has tripped.
 - ii. Reboot the power to the controller by disconnecting its power cord for a few seconds and reconnecting it. If there are blue LED lights blinking on the front display, wait until these lights stop blinking.
 - iii. Check the Tripp Lite (or equivalent) surge suppressor that the sampler is plugged into (this may be located inside the pump enclosure). There should be a two green lights on the surge suppressor.
 - iv. Check the power cord for the sampler. This black or gray cord runs from the base of the control module to the power surge suppressor. If it is unplugged, reconnect it.
 - v. If you are still not sure if power is on:
 - (a) Unplug one of the pumps from its gray relay box. Relay box will have either red and yellow, green and blue, or orange tape on it.
 - (b) Plug the pump power cord directly into the power surge suppressor. The pump will start if there is power.
 - (c) Plug the pump back into the duplex outlet box.

6.1.3 *The elapsed time is zero for one or multiple days.*

Check the following to determine why sampling did not occur on the scheduled day. Describe the problem on the logsheet. You will likely receive a low ET warning (Figure 6-1). If you cannot determine the cause of the problem call UC Davis at (530)752-1123 as soon as possible.

- i. Check that the date and time on the controller screen are correct. Adjust if necessary as described in Section 6.2.
- ii. If possible, check whether there was a power outage at any time that entire day.
- iii. Look at the Module 1A filter that has an elapsed time of zero. Does the filter look white like a new filter or does it look like there is a sample on the filter?

Figure 6-1. Low ET warning.



6.1.4 *Pump will not start.*

- i. Check that the pumps are all plugged in (the gray relay box the pump is plugged into may have a red switch on it but this is not connected and does not control the pump power).
- ii. Test the pump that is not starting by doing the following:
 - (a) Unplug the pumps that are in question from their gray relay box.
 - (b) Plug the pump cord directly into a working A/C outlet. If the pump starts, the problem is with the relay box. Ensure the A/C outlet is functional.
 - (c) If the pump does not start, the problem is with the pump.
 - (d) Plug the pump back into the duplex outlet box.
 - (e) Call UC Davis and describe the results of the test.
- iii. Extreme cold may prevent pumps from starting. Remove the pump to a warm location (or come back when the weather is warmer) and test. If cold weather is found to be the problem, try one of the following solutions:
 - (a) Run pumps continuously by plugging them into unswitched outlets (power strip or wall outlet).

- (b) Keep pumps warm by placing an automotive electric blanket or other heat source under the pumps.

6.1.5 *Pump starts slowly.*

Note the slow starting pump on the logsheet and contact UC Davis. If the weather is extremely cold see Section 6.1.4.iii above. If the pump is slow to start in normal temperatures, it needs repairs. Contact UC Davis and a new pump will be shipped to the site to replace the malfunctioning pump.

6.1.6 *The motor drive for the cartridge manifold is not working.*

The motor can be disengaged, and the hand wheel can be used to manually raise and lower the cartridge manifold. The motor drive for the PM_{2.5} module is shown in Figure 3- and for the PM₁₀ module is shown in Figure 3-. For the PM_{2.5} module, push down on the top of the drive while pulling the bottom outwards. Then swing the motor to the left to lock it in the disengaged position. The hand wheel may now be used to raise or lower the solenoid manifold. The procedure is the same for the PM₁₀ module (4D) except the motor is upside down compared to the PM_{2.5} modules. The PM₁₀ module (4D) motor must be pulled up and pushed to the right to disengage. Notify UC Davis of the motor problem by calling (530-752-1123) or making a note on the logsheet.

6.1.7 *The plastic motor coupler broke or came off.*

If the motor spins when the raise/lower switch is pressed, but the manifold does not move, the plastic motor coupler might have broken or fallen off. If the motor coupler came off, insert the coupler back on top of the motor (procedure is similar to 6.1.6 disengaging the motor). If the coupler is broken, use the hand wheel to raise/lower the manifold for filter change and notify UC Davis to get a replacement motor coupler.

6.2 Sampler Configuration

Change Date and Time:

To change the current date and/or time, press the **Menu** button from the Home Screen. Then press the **Settings** button. The Settings menu is shown in Figure 6-2. The menu option for **Network Time Sync** will cause the controller time to sync with the connected network device. This can either be enabled or disabled. The operator can change the time using the **Date and Time** button (Figure 6-3) when **Network Time Sync** is disable. The **Time Zone** button allows the operator to change the Greenwich Mean Time (GMT) offset (Figure 6-4). An invalid date is one that does not exist in the month (e.g., 2/30 or 9/31).

Figure 6-2. Settings Menu.

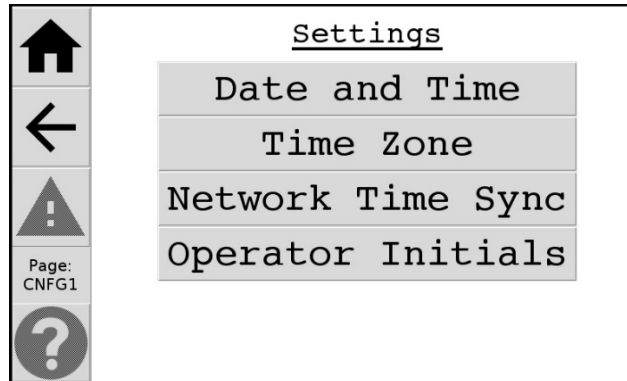


Figure 6-3. Change date and time screen.

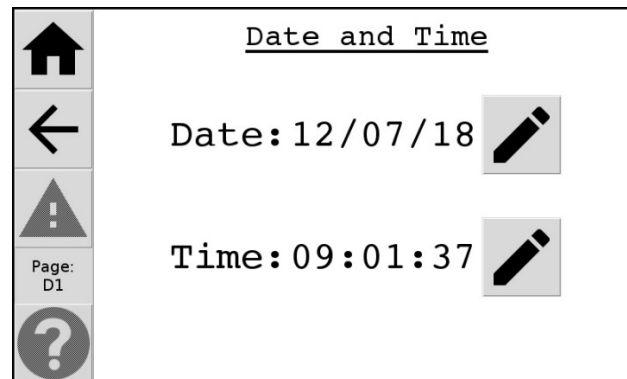
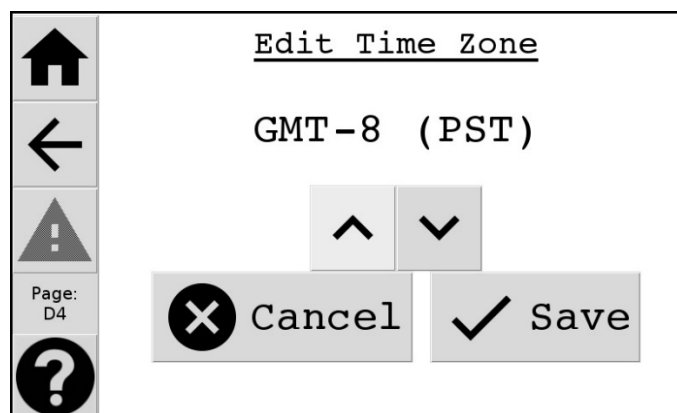


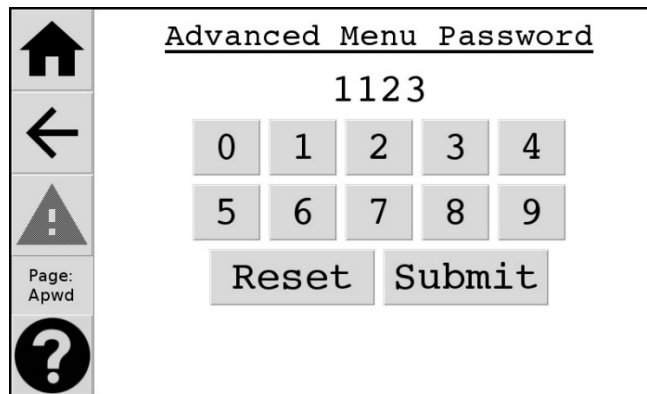
Figure 6-4. Change Time Zone screen.



Advanced Menu:

Press the **Menu** button on the controller Home Screen to access the main menu. Press the **Advanced Menu** button to access the Advanced Menu. The Advanced Menu should not be accessed unless authorized by UC Davis. Enter the code **1123** to access controller parameters.

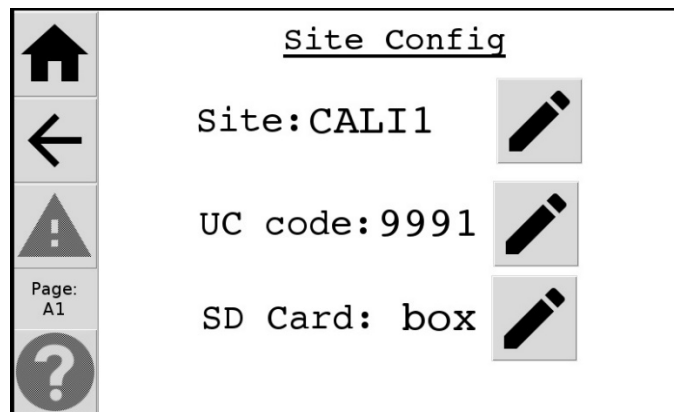
Figure 6-5. Advanced Menu Password screen.



The screen displays the title "Advanced Menu Password" at the top. Below the title, the password "1123" is entered. A numeric keypad with digits 0-9 is shown, along with "Reset" and "Submit" buttons. On the left side, there is a vertical menu with icons for Home, Back, Warning, Page: Apwd, and a question mark.

Once accessed, the operator will be able to configure parameters on the sampler by pressing the **Site Config** button. This menu will allow the operator to check and change, if necessary, the sampler configuration including the site name, UC Code, SD card change type, and sampling schedule.

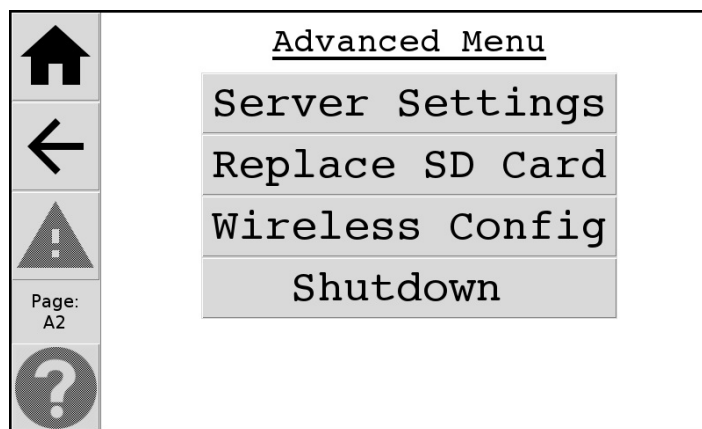
Figure 6-6. Site Config.



The screen displays the title "Site Config" at the top. Below the title, there are three configuration items: "Site: CALI1", "UC code: 9991", and "SD Card: box". Each item has a pencil icon to its right, indicating it can be edited. On the left side, there is a vertical menu with icons for Home, Back, Warning, Page: A1, and a question mark.

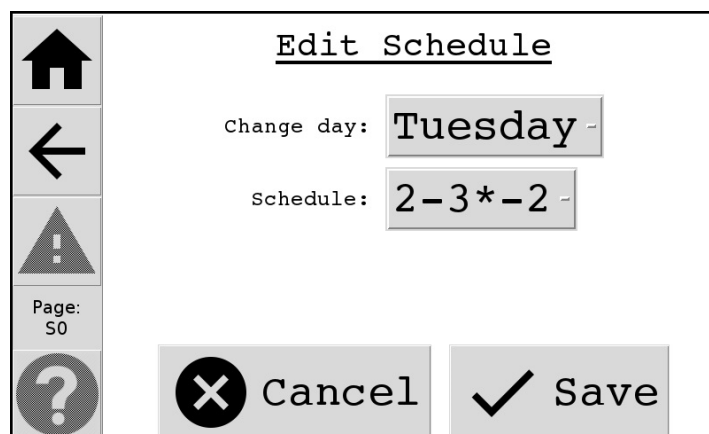
Shutdown and Restart: The **1123** advanced menu can also be used to shut down or restart the controller without pulling the power cord. From the Advanced Menu, press the **More** button, then **More** again, then the **Shutdown** button. Depending on what procedure is necessary, press either the **Restart** or **Shutdown** button, and follow the instructions on the screen.

Figure 6-7. Shutdown.



Blue Box sequence: From the **Advanced Menu** press the **More** button, then **Edit Schedule**. This screen allows the user to specify the cartridge sequence of the Blue Boxes. To edit the Schedule there are two choices: 3*-2-2) the Blue Boxes, when received from UC Davis, have three cassettes in the first week and two cassettes in the second and third weeks (Sequence 322), or 2-3*-2) the Blue Boxes have two cassettes in the first week, three cassettes in the second week, and two cassettes in the third week (Sequence 232). The default sample change day should be Tuesday and should not be edited.

Figure 6-8. Edit Schedule.

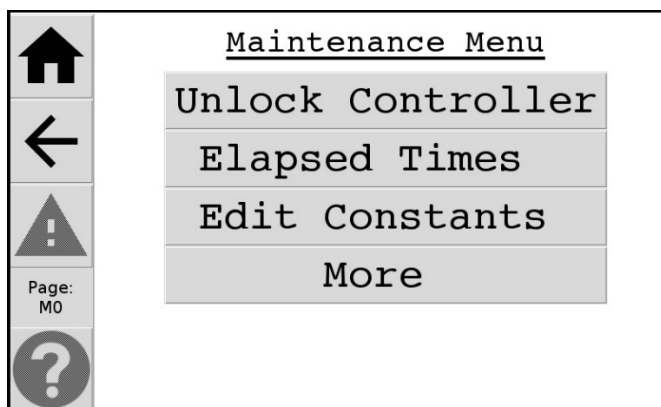


Maintenance Menu:

Press the **Menu** button on the controller Home Screen to access the main menu. Press the **Advanced Menu** button to access the passcode input screen. Enter the code **9051** to access the **Maintenance Menu** which provides more advanced controller parameters and calibration. It is easy to configure the controller wrongly so this menu should only be accessed by maintenance

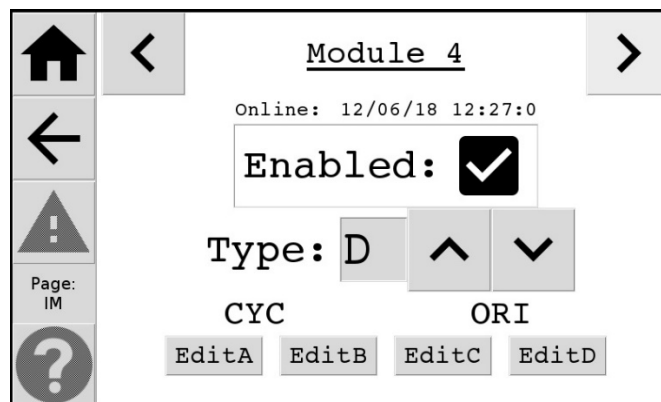
technicians or with careful instruction. Erroneous configuration could result in the sampler failing to sample.

Figure 6-9. Maintenance Menu.



Module types: Press **More** from the **Maintenance Menu**, then the **Config Modules** button. This menu option is used to specify the number and type of modules operating at the site. The default configuration for the IMPROVE network is a four module setup with modules 1A, 2B, 3C, and 4D. If the current information is correct, press **ENTER** to save. Otherwise, enter the correct information and press **ENTER** to save.

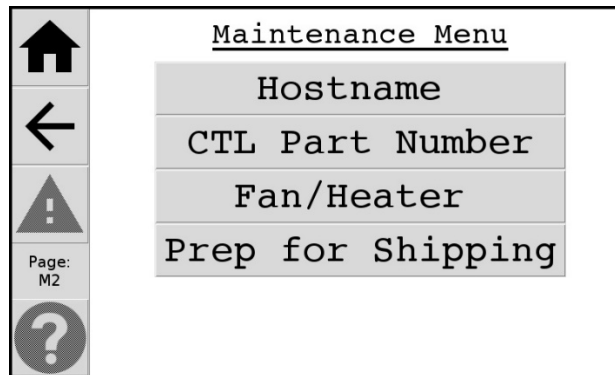
Figure 6-10. Edit Module.



X Module Type: The Module 5 configuration screen is used to select what type of sampler the X module (if present) will be. Module 5 should have the Enabled box checked, and should have the Type configured to the appropriate setting. Types are as follows: A) PM_{2.5} Teflon; B) PM_{2.5} Nylon; C) PM_{2.5} Quartz; D) PM₁₀ Teflon.

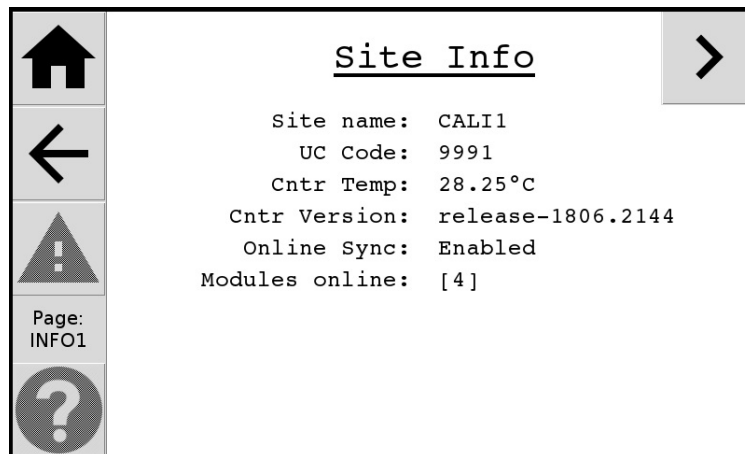
Controller ID: This screen allows the user to specify the inventory number assigned to current controller and hostname. The operator cannot configure these options without a keyboard, and in most cases will never need to. The Controller Part Number is found on the interior right wall of the controller and the hostname is found under the faceplate of the CPU Card.

Figure 6-11. Controller Part Number.



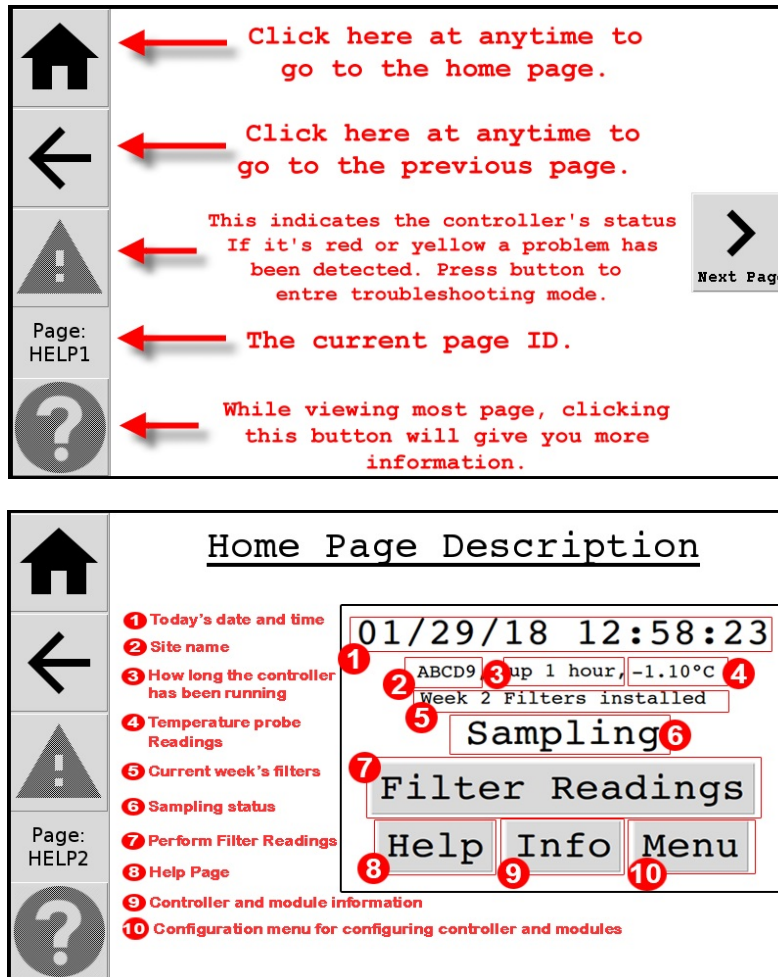
Info Screen: The Info Screen is accessed by pressing the **Info** button from the home screen. This screen summarizes the configuration and displays the firmware version number (release-1806.2144 shown here).

Figure 6-12. Site Info.



Help Screen: The Help Screen is accessed by pressing the “?” button from any screen it is available on. From the Home Screen, the “?” will display the following information about the Home Screen.

Figure 6-13. Help screen.

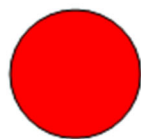


APPENDIX I: ELEVATION FACTORS

Table AI-1. Elevation factors for a range of elevations. The elevations are listed in units of both meters (m) and feet (ft) above mean sea level. The pressure in units of millimeters of mercury is also listed for each elevation.

Elevation (m)	(ft)	F(elev)	P (mmHg)	Elevation (m)	(ft)	F(elev)	P (mmHg)	Elevation (m)	(ft)	F(elev)	P (mmHg)
0	0	1.000	29.90	1200	3,936	1.075	25.88	2400	7,872	1.158	22.32
50	164	1.003	29.72	1250	4,100	1.078	25.73	2450	8,036	1.161	22.18
100	328	1.006	29.55	1300	4,264	1.081	25.57	2500	8,200	1.165	22.04
150	492	1.009	29.37	1350	4,428	1.085	25.41	2550	8,364	1.168	21.90
200	656	1.012	29.20	1400	4,592	1.088	25.26	2600	8,528	1.172	21.76
250	820	1.015	29.02	1450	4,756	1.091	25.10	2650	8,692	1.176	21.63
300	984	1.018	28.85	1500	4,920	1.095	24.95	2700	8,856	1.180	21.49
350	1,148	1.021	28.68	1550	5,084	1.098	24.80	2750	9,020	1.183	21.35
400	1,312	1.024	28.51	1600	5,248	1.101	24.65	2800	9,184	1.187	21.22
450	1,476	1.027	28.34	1650	5,412	1.105	24.49	2850	9,348	1.191	21.09
500	1,640	1.030	28.17	1700	5,576	1.108	24.34	2900	9,512	1.195	20.95
550	1,804	1.033	28.00	1750	5,740	1.112	24.19	2950	9,676	1.198	20.82
600	1,968	1.036	27.83	1800	5,904	1.115	24.05	3000	9,840	1.202	20.69
650	2,132	1.040	27.67	1850	6,068	1.119	23.90	3050	10,004	1.206	20.56
700	2,296	1.043	27.50	1900	6,232	1.122	23.75	3100	10,168	1.210	20.43
750	2,460	1.046	27.34	1950	6,396	1.126	23.60	3150	10,332	1.214	20.30
800	2,624	1.049	27.17	2000	6,560	1.129	23.46	3200	10,496	1.218	20.17
850	2,788	1.052	27.01	2050	6,724	1.133	23.31	3250	10,660	1.221	20.04
900	2,952	1.055	26.84	2100	6,888	1.136	23.17	3300	10,824	1.225	19.91
950	3,116	1.059	26.68	2150	7,052	1.140	23.02	3350	10,988	1.229	19.79
1000	3,280	1.062	26.52	2200	7,216	1.143	22.88	3400	11,152	1.233	19.66
1050	3,444	1.065	26.36	2250	7,380	1.147	22.74	3450	11,316	1.237	19.53
1100	3,608	1.068	26.20	2300	7,544	1.150	22.60	3500	11,480	1.241	19.41
1150	3,772	1.072	26.04	2350	7,708	1.154	22.46	3550	11,644	1.245	19.28
1200	3,936	1.075	25.88	2400	7,872	1.158	22.32	3600	11,808	1.249	19.16

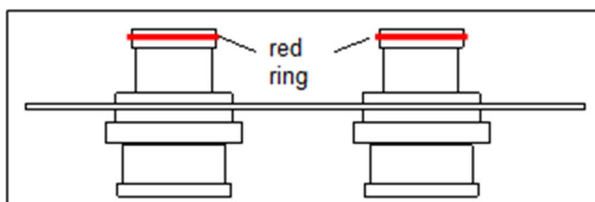
APPENDIX II: MODULE DOOR QUICK REFERENCE SHEETS



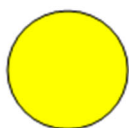
Version II IMPROVE Sampler Module 1A—Red Dot on Cartridge

Air Quality Research Center
University of California, Davis

Cassette Orientation
Labels and Red O-ring UP



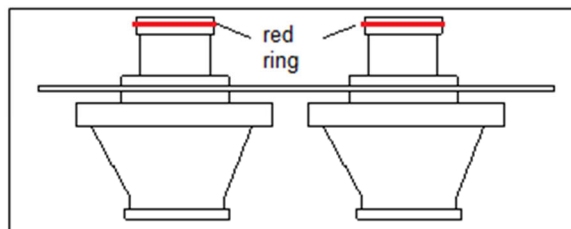
All cartridges must have four cassettes.
Never install a cartridge with a hole.
Get cassette with black O-ring from last week.



Version II IMPROVE Sampler Module 2B—Yellow Dot on Cartridge

Air Quality Research Center
University of California, Davis

Cassette Orientation
Labels and Red O-ring UP



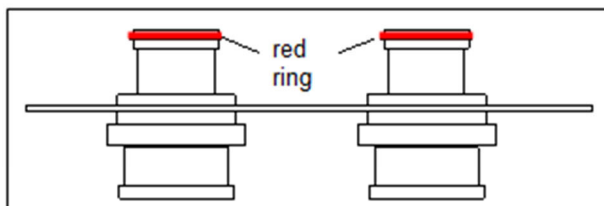
All cartridges must have four cassettes.
Never install a cartridge with a hole.
Get cassette with black O-ring from last week.



Version II IMPROVE Sampler Module 3C—Green Dot on Cartridge

Air Quality Research Center
University of California, Davis

Cassette Orientation
Labels and Red O-ring UP



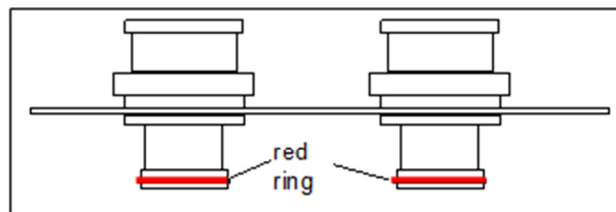
All cartridges must have four cassettes.
Never install a cartridge with a hole.
Get cassette with black O-ring from last week.



Version II IMPROVE Sampler Module 4D (PM₁₀ inlet)—Blue Dot on Cartridge

Air Quality Research Center
University of California, Davis

Cassette Orientation Reversed
Labels and Red O-ring DOWN



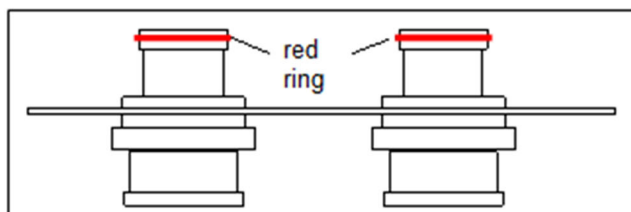
All cartridges must have four cassettes.
Never install a cartridge with a hole.
Get cassette with black O-ring from last week.



Version II IMPROVE Sampler Module 5X—Orange Dot on Cartridge

Air Quality Research Center
University of California, Davis

Cassette Orientation
Labels and Orange O-ring
UP



All cartridges must have four cassettes.
Never install a cartridge with a hole.
Get cassette with black O-ring from last week.