UCD IMPROVE SOP #226 Technical Instruction

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TI 226A: Site Maintenance for Field Technicians

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1. PURPOSE AND APPLICABILITY

This technical instruction (TI) details the procedures the field technicians must follow for routine maintenance of equipment in the IMPROVE sampling network. Prior to 2013, routine site maintenance occurred on a yearly basis. Starting in January 2013, sites will receive biennial maintenance, with half of the network receiving maintenance one year and the other half the next year. Routine maintenance is divided into "loops," with an average of ten sites visited on each loop. Maintenance is solely the responsibility of the Air Quality Research Center's field operations team, comprised of the field manager and field technicians.

2. SUMMARY OF THE METHOD

Prior to routine maintenance, the field technician will review and summarize all of the information collected at each site during the previous year(s) in order to characterize how well each site is functioning. The data recorded during weekly visits to the IMPROVE samplers by the operators, as well as any problems detected during quality assurance procedures, will be incorporated into the site summary. This reference will be used to determine whether extra maintenance or troubleshooting is required at each site. The Air Quality Research Center (AQRC) will establish and announce a rough maintenance schedule for the year.

Routine site maintenance will be performed by AQRC field technicians. During the site visits the cyclones, stacks, and inlets are cleaned; the electronics are checked; the pumps are flagged for replacement or repaired as needed; the sampler flow rates are checked; and calibration equations are verified. Operator training and review sessions as well as any sampler upgrades are also performed at this time.

3. DEFINITIONS

- Cassette: a plastic holder that contains a filter substrate or dummy.
- Dummy: a 25 micrometers (mm) or 37 mm piece of material used in cassettes that are not sampled.
- Cartridge: consists of a cartridge plate and 3-4 cassettes inserted in the cartridge plate.
- $PM_{2.5}$: Particulate matter, aerodynamic diameter of 2.5 mm or less.
- PM_{10}: Particulate matter, aerodynamic diameter of 10 mm or less.
- 1A module: one of four channels routinely run at every site in the IMPROVE network. Measures $PM_{2.5}$ with Teflon® as the filter medium and runs at 23 liters per minute.
- 2B module: one of four channels routinely run at every site in the IMPROVE network. Measures $PM_{2.5}$ with nylon as the filter medium and runs at 23 liters per minute.
- 3C module: one of four channels routinely run at every site in the IMPROVE network. Measures $PM_{2.5}$ with quartz as the filter medium and runs at 23 liters per minute.

- 4D module: one of four channels routinely run at every site in the IMPROVE network. Measures PM_{10} with Teflon® as the filter medium and runs at 16.9 liters per minute.
- Cyclone: IMPROVE particle size separator based on aerodynamic equivalency diameter of 2.5 mm.
- Denuder: Set of concentric aluminum tubes used to remove nitric acid from air stream.
- Ebox: Electronic box which houses pressure transducers and manifold drive relays.
- Rbox: Relay box which houses relays that turn on pumps.
- lpm: liters per minute.
- Stack: Inlet tube for module.
- Inlet: Cap over $PM_{2.5}$ stack with insect screen.
- Magnehelic: Device that measures differential pressure used for flow checking modules.
- Sierra inlet: EPA Louvered PM_{10} Inlet.

4. HEALTH AND SAFETY WARNINGS

Be aware that various stinging insects, venomous creatures, and large mammals (such as bears) can be found at many of the IMPROVE sites. Be cautious when stepping in tall grass surrounding a site or when opening pump boxes.

Maintenance requires cleaning of the stack inlets, which typically requires accessing the roof of a structure. Safety ratings are assigned to classify fall risk at each site. These ratings range from "None," "Low," "Medium," to "High." The field manager and technician will meet to discuss the fall safety plan determined for accessing and cleaning the inlets and stacks.

Inclement weather is often an issue at many IMPROVE sites. If severe weather is impending, wait it out in the vehicle or reschedule the site visit.

Always carry a first aid kit. Report any injuries to the field manager immediately.

Refer to TI 226G for more information.

5. CAUTIONS

Many access roads to IMPROVE sites are locked after regular business hours. Be sure to communicate with any necessary staff how long the visit is expected to take to avoid being locked in the area.

Some IMPROVE sites are remote and require hiking to the site or driving off-road. Be sure to have detailed directions on how to get to a site that requires walking or off-road driving.

Many IMPROVE sites do not have cellular reception. Take this into consideration when planning site visits.

Wasps and rodents sometimes make nests in the inlets and the sampler enclosure. Check for this carefully, as this can cause issues during sampling and other health concerns. Report any infestations in the sampler to the field manager immediately.

There are several urban IMPROVE sites and care should be taken to lock vehicles and secure work and personal equipment while at the site.

6. INTERFERENCES

Occasionally, due to weather conditions or the way a site is housed, the 4D module stack at a site may rub against the funnel. This situation results in the formation of a black powder, referred to as "anodizing dust," that collects and falls down onto the filters. During site maintenance, check to make sure there is no sign of anodizing dust on any of the 4D module filters at the site before and during maintenance. If any anodizing dust is present on the filters, flag the site as a candidate for a stack-stabilizing tripod, take detailed pictures of the roof where the tripod will sit, and inform the field manager. If any anodizing dust is found in the funnel, locate the cause and flag any equipment that needs replacing.

7. PERSONNEL DUTIES

The field manager will:

- Oversee and maintain records of site and sampler operation
- Organize and schedule maintenance loops
- Review flow rate checks and flow rate adjustments
- Oversee the training of field technicians both at the AQRC and in the field
- Respond to any issues or concerns brought up by field technicians during maintenance

The site operator will:

- Note deviations from normal operations and inform AQRC personnel
- Attend site operator training and review sessions during site maintenance
- Replace equipment when requested by field operations
- Maintain a clean site

The field technician will:

- Perform routine site maintenance
- Perform site operator training and review sessions
- Maintain records on equipment repair and modification
- Report any issues or concerns in the field to the field manager

8. EQUIPMENT AND SUPPLIES

The equipment list for site maintenance trips will vary depending on the number of sites that will

be visited and whether any new sites will be installed during the trip. Because of this and due to the extensive amount of supplies needed, equipment lists will not be reported within this TI. They can be located in Attachment 1, "Maintenance Packing Lists" of *UCD SOP #226: Site Maintenance.*

9. PROCEDURAL STEPS

Field technicians perform routine site maintenance, generally in the spring or summer. This visit to the site is an opportunity to flag non-vital sampler components for replacement, verify calibration equations, replace or update obsolete equipment, thoroughly clean each sampling module, and test the vacuum systems. It also allows trained personnel to inspect the site to ensure compliance with EPA sampling regulations and provides an excellent opportunity for operator training.

The following sections describe the site maintenance procedure:

9.1. Preparation for Site Maintenance Loop

9.2. Operator Training and/or Review

9.3. Pre-Maintenance Procedures at the Site

9.4. Initial Flow Rate Check

9.5. Leak Check of the Sampling Modules

9.6. Sampler Cleaning and Maintenance

9.7. Detailed Inspection of Components and Housing

9.8. Leak Check of the Sampling Modules

9.9. Final Flow Check/ Calibration Verification

9.10. Post Calibration Verification and Documentation

9.11. Update Equipment Inventory

9.12. Take Photos of the Site and Equipment

9.1 Preparation for Site Maintenance Loop

Preparation for site maintenance involves contacting each site, scheduling visit dates and times, and creating a site flow check and maintenance kit. The field manager is responsible for scheduling maintenance trips and overseeing the training and supplying of the field technicians, both prior to leaving the AQRC and while in the field. The process to prepare for site maintenance is described below.

1) The field technician notifies the site operator of the impending visit two to four weeks prior to the scheduled date. The following topics are covered during operator notification:

   - The exact date and time of scheduled maintenance at the site.
   - Scheduling of operator training sessions or review. The operator should

agree to meet for at least twenty minutes so that any changes to the site can be explained.

- Details of site access, including keys, combinations, etc.
- Current problems with the sampler, power, site, etc.
- Past performance/collection rate of the sampler (if requested by the operator or if the collection rate is low).

2) The field technician prepares the following documents:

- Site access sheets.
- Site information.
- Site data.
- Sample log sheets for each site.
- Maintenance checklist (one for each site; tasks should be checked off on the checklist as they are performed).
- Labels (for controller and electronics boxes).
- Notes generated during maintenance preparation meeting with field manager.
- History of all equipment replaced since last maintenance. Also, include any out of the ordinary troubleshooting that has occurred at the site that will provide insight on any other problems that may be encountered during the visit.
- Maintenance loop schedule. Check with the field manager to see if any sites have time restrictions.

3) The field technician must prepare the flow check devices and flow adjustment cartridges. First, the field technician must select two complete flow check devices (one as primary and the other as backup). The field technician must also prepare two sets of cartridges: one set for the flow rate check (with old lot nylon filters) and the other set for flow adjustment (new lot nylon filters). Teflon® and quartz filters are typically very stable without significant changes from lot to lot, so the Teflon® and quartz filters can be loaded from the current open box of filters in the lab. Teflon® filters from the lot are used for both 1A and 4D cartridges. Quartz filters are used for 3C cartridges. Nylon filters, however, vary in resistance significantly between each other. Many 2B filters of both the old lot and the new lot must be tested and the one with average resistance in each lot must be selected and loaded in the cartridges. The field technician must also bring extra filters, as each filter should not be used for more than three sites. Use the following equation to determine the number of additional filters to bring:

(# of sites) ÷ 3 = (# of filters to prepare)

4) The field technician checks the calibration of the two flow check devices with the

BIOS Definer 220. If the flow rates are not within 2% of the previous device calibration, the flow checking device is recalibrated.

5) The field technician assembles a tool kit and organizes a comprehensive parts kit. Parts and tools required for basic electrical and carpentry tasks should be included. At this time, the maintenance loop documents should be reviewed to determine any extra work or suspected problems for which the technician must be prepared.

6) The field technician prepares clean, coated denuders to replace the used denuders in the 2B modules at each site. For instructions on how to clean and coat each denuder, please see TI 226D.

7) The field technician ships the maintenance gear before departing on the maintenance trip if applicable.

9.2 Operator Training and/or Review

Once at the site, the field technician should meet with the operator and discuss the following:

- Introduce any new hardware/software that will be installed. Talk about any changes the operator will see and leave behind an explanation letter, sample change SOP, site contact info update form, and site report.
- Ask about any concerns or pending problems at the site. Make sure that all of the problems are addressed before leaving the site. If a particular problem cannot be resolved, leave a note or call the operator and explain what the plan is to resolve it in the near future. Call the lab for assistance or equipment if needed.
- Explain the range of temperature values that the operators should expect.
- Show the operator where the AQRC lab number is located on each log sheet and on the controller door instructions.
- Stress the importance of reporting if the time on the controller drifts more than five minutes ahead or behind actual time. Also remind them that all IMPROVE network controllers should run on standard time, and that the operators should not adjust the controller to match DST. Controllers that are connected to an internet device should sync their time automatically, and should not need to be adjusted.
- Stress the importance of writing comments in the comment section of the log sheets for minor issues. These comments are vital in helping the AQRC lab determine when equipment has failed, been requested, and been replaced.
- In addition to writing comments, stress the importance of also calling the lab, especially if equipment seems to be malfunctioning or when equipment is replaced.

If there is a new operator for the site who has not received training, make sure to set aside time to train the operator on sample change procedures. Site operator training involves review of the materials covered in *UCD SOP #201: Sampler Maintenance by Site Operators*. The site operator must be trained to perform the following tasks:

- Recording of the final readings for exposed filter cassettes
- Removal of exposed filter cassettes
- Installation of clean filter cassettes
- Recording of initial readings for the clean filter cassettes
- Memory card installation
- Shipping/mailing procedures for the return of exposed filter cassettes and log sheets
- Air Quality Research Center phone numbers
- 4 letter site name code
- Basic troubleshooting procedures
- Overview of the site flow rate check procedure, as operators are occasionally required to perform audits due to significant changes in flow, equipment, replacements, etc.
- Replace some of the basic components, including the controller, electronics boxes (Eboxes), and pumps
- Ability to disengage the manifold motors in case they stop working between maintenance visits

9.3 Site Maintenance

9.3.1 Pre-Maintenance Inspection at Site

Prior to maintenance of the sampler, inspect the site for any general repairs needed. Any repair or changes to the sampler or site should be noted. The following is a review of the suggested pre-maintenance procedures:

1) Determine the location of the breaker for power to the sampler.
2) Check the integrity of the sampler stand, noting any parts that require repair or replacement.
3) Note the condition of the sampler modules (e.g. are they rusted?)
4) Visually inspect the sample cassettes. Note and correct any errors involving the sample change protocol.

Take final readings on any samples that are complete and record them on the appropriate log sheet. If the blue box and log sheet are not available, make sure to record the information in the flow check/flow adjustment spreadsheet and transmit it to the sample-handling laboratory upon returning from maintenance.

If the controller is running upon arrival, the field technician needs to record the elapsed time of the running samples. Record the final PRES/ORI and FLOW/CYC values for the sample currently running and then take new initial readings for the sampler after the conversion and flow calibration. With this particular type of conversion, the calibration equations will be changed significantly and thus PRES/ORI and FLOW/CYC values for each section of data (before and after maintenance) are needed. Record these values on the log sheet.

Write them down in the flow check/flow adjustment spreadsheet if the log sheet is unavailable, and transfer the values onto the log sheet when it returns from the field.

Write a note in the comment section of the log sheet (if available) mentioning the visit. For example, "Site maintenance performed on 9/5/2017 by JSG. ET stopped at 800."

9.3.2 Flow Rate Check

1) Remove the sampling cartridges from the modules, replace their red caps, and place them in Ziploc bags in their blue box or another clean area.
2) Disconnect the temperature probe from the 3C module and place the tip of the probe in the shade. Place the NIST certified digital thermometer in the shade next to the 3C (or whichever applicable) module's temperature probe and allow it to reach equilibrium (approximately five to ten minutes). Record the current temperature (°C) from the controller home screen and the temperature (°C) from external thermometer, and fill in the flow check portion of the flow check/flow adjustment spreadsheet.
3) Record the Vac/Max Orifice reading and zero flows for all the modules. Vac/Max Orifice is checked with pump on, all solenoids closed, and zero flows can be measured with a solenoid open and pump off, both from the Calibration menu option.
4) Perform the flow check. Make sure the magnehelic dial is perfectly zeroed before starting. The hoses attached to the dial must be completely straight through the length of the protective springs; otherwise, the dial will shift. Sites with a fifth module formerly referred to the fifth module as an X module. These modules are now referred to as either 5A, 5B, 5C, or 5D to designate what type of filter media is used, and what particle size is collected. Remember that fifth position modules (X modules) do not have their own special cartridge. Use the same cartridge as the module that the fifth module represents (1A, 2B, 3C, or 4D). See TI 226B for step-by-step instructions on how to perform the flow check.
5) Review the flow check results. Compare the nominal values to the previous year's values. The errors generated through the flow check should be under 5%. If large errors occur, remember to review the problems noted pre-maintenance. Electronic box, controller replacements, or previous flow adjustments may account for large errors. Call the lab if phone reception is available so that a lab staff member can confirm whether they have seen these large errors in the data from blue boxes. If the data from blue boxes is different from the results of the flow check, a recent problem may have occurred with the module. Record all original flow check values for all four positions in the flow check spreadsheet. Select solenoid 1 on the controller and then try to wiggle the valve without actually turning it. If the magnehelic values change, note all these new values in the spreadsheet. If in doubt, call the lab for help.
6) Perform pre-leak check of all sampling modules. Make sure to first equilibrate the vacuum gauge. Use the plug and extension bar from the flow check probe to check the vacuum reading from each pump and module to ensure that the readings from each pump and its corresponding module are similar. If a difference between pump and module is greater than 2.0" Hg, a leak in the vacuum system was pre-existing.

Fixing the leak is not necessary at this step, but locating the leak is very important in the next step. Leaks may arise from a bad alignment on the cyclone between the cyclone block and funnel, from loose valves, torn O-rings, or a cyclone that needs shimming.

9.3.3 Sampler Cleaning and Maintenance

9.3.3.1 Clean Cyclones

1) Remove the cyclones in the 1A, 2B, and 3C modules. Move the cyclones to an area where they can be cleaned comfortably and where there is low risk of dropping any tools or parts into dirt, water, etc.
2) As each cyclone is disassembled and reassembled, check each O-ring. If any O-ring is damaged or missing, replace the part or replace the O-ring with a vacuum-greased BUNA O-ring and report it in the site notes. When working with cyclone assemblies, use caution when using metal tools as they can damage the anodized surface. All internal surfaces of the cyclone assembly should be cleaned with alcohol and laboratory wipes.
3) Clean the 4D module funnel. Note that this requires removing the lid.

9.3.3.2 Clean the Stacks, Inlets, Tees, and Stack Bottom Plugs

1) Remove the stack bottom plugs, checking the O-rings and replacing the entire plug if they are damaged. Clean the Tees with alcohol and laboratory wipes.
2) Remove and clean the inlet caps from the top of the stacks. Check and replace the O-rings if necessary. Use laboratory wipes and alcohol to clean the screen and remove dust and any spider webs. Wasps and other stinging or biting insects sometimes build nests in the inlets, so use caution when removing them and notify the field manager if any wasp nests are found.
3) For the Sierra inlet, which is located on the 4D stack:
    - Unscrew the water trap bottle, either plastic or glass, from the metal cover.
    - Empty the bottle and wipe out any sediments or materials that have collected inside it or on the metal cover. Check for cracks or chips. If the cup is damaged in any way, replace it immediately. Inspect the water trap bottle gasket for damage or excessive wear.
    - Reinstall the water trap bottle.
    - Unscrew the four Phillips head screws on the underside of the louvered flaps of the inlet and remove the top plate. Clean the cone attached to the top plate and the inlet funnel with alcohol and a lint-free laboratory wipe.
    - Clean the exit tube for the inlet funnel with a cotton-tipped applicator and alcohol.
    - Reassemble the inlet. If any of the screws appear to be stripped, replace them. They are 8-32 x ½" Phillips head screws. Use anti-seize when replacing any screws and/or standoffs.

- Hold the top of the inlet with one hand, grasp the pipe to the water trap bottle with the other hand, and unscrew the inlet top from the body at the seam located 7½" above the base of the inlet.
- Clean the impaction surface thoroughly with lint-free cloths and alcohol.
- Clean all interior surfaces with lint-free clothes or cotton-tipped applicators and alcohol.
- Reassemble the inlet head.
- Check the O-rings inside the stack sleeve, replacing them if necessary. They are ethylene propylene O-rings size 200-026 and are easily removed using a knife blade.
- Coat the O-rings in the stack sleeve and exit funnel with vacuum grease.

4) Remove the denuder from the 2B module by raising the stack, then removing the denuder detent O-ring. The denuder will now drop out of the Tee, or it can be pulled out of the top of the module if the stack is removed.
5) Clean the inlet stacks using a stack brush. Clean each stack at least twice.
6) Use alcohol and a clean rag or laboratory wipes to clean the inlet Tee. Inspect and replace any damaged O-rings.
7) Reinstall the inlet caps

9.3.3.3 Clean the Interior of the Module and Check All Hoses, Wires, and Connectors

1) Brush out the bottom of the modules to eliminate fugitive dust and insects. Be sure the vents are clear of debris.
2) Remove the needle valve stems carefully using a ¾" wrench. Clean the inside of the valves with a cotton-tipped applicator and then reinstall them.
3) As of 2016, all needle valves network-wide are facing outward. If this is not the case, the jam nut on the valve body is loosened, the valve is clocked 90°, and upper CPC and coupler are reoriented to face right, pointing towards the cyclone. Valves are cleaned after being reconfigured.
4) Check for cracked or aged hoses on the cyclone. Clip any damaged ends or, if the tubing is showing signs of wear, replace it with new tubing.
5) Use wire ties and anchors to keep wires out of the way of the site operator.

9.3.3.4 Pump Maintenance and Equipment Replacement

1) Listen to each pump to determine whether any of them are making unusual noises. Record the rebuild dates for all the pumps. Determine whether pumps need to be rebuilt.
2) Replace any version II 4D funnels with version I funnels. These version II funnels are now rare.

3) Replace any grommets on module cases that have weathered and cracked.
4) Replace any broken or cracked manifold motor couplers.
5) As of 2017, if a motor coupler disk is fixed to motor coupler hub, remove nut and screw and free the motor coupler disk, allowing for easier replacement.
6) Replace the used denuder with a clean, coated denuder. Make sure to record the inventory number of the new denuder in the site notes.

9.3.3.5 Inspect the Sampler Stand or Structure and the Pump House/Area

Look for deterioration of the stand or structure and the pump house or area, recording any issues in the site maintenance notes. The modules should be securely attached to the mounting structure, and the stacks should be firmly seated. The pumps should be in an area that has enough airflow for effective cooling, and the area should be free from pest infestation. Inform the field manager if there are any issues that need to be addressed immediately.

9.3.4 Post-Leak Check All Modules

Return all equipment to its proper location and perform a leak-check of all the modules.

Make sure to first equilibrate the vacuum gauge. Use the plug and extension bar from the flow check probe to check the vacuum reading from each pump and module to ensure that the readings from each pump and its corresponding module are similar. Pump and module differences cannot be greater than 2.0" Hg. If a difference is greater than 2.0" Hg, investigate to determine what is causing the leak. Leaks may arise from a bad alignment on the cyclone between the cyclone block and funnel. Adjust the play in the two mating pieces. Leaks may also arise because of a loose valve, torn O-rings, or a cyclone that needs realignment/shimming. Refer to TI 226E for step-by-step instructions.

9.3.5 Record Zero Flows

The zero flows for all primary modules should be 14.7 psi at sea level for the PRES/ORI value and ~0.0 in H_2O for the FLOW/CYC value, depending on the individual sensor. X module values will match the primary module during flow adjustment. Please see TI226C for step-by-step instructions on how to perform the procedure. **Note:** zero values are no longer manually adjusted.

9.3.6 Module Flow Rate Adjustment

Verify or adjust the flow rate on the modules. Note that the lot number of the nylon filter cartridges are tracked for the 2B module (as well as the X module, if applicable). For step-by-step instructions on how to prepare for flow adjustment, please see TI 226C.

1) From the Home Screen of the controller, press the **Menu** button, then **Advanced Menu** button, enter **9051**, press the **More** button, then **Flow Adjustment**. Starting with the 1A module (or applicable first configured module), open solenoid 1 by pressing **S1: Off** so that it reads "**S1: On**" on the appropriate module. Press "**Pump: Off"** so that it reads, "**Pump: On"**. The flow rate should be adjusted only on a clean filter in solenoid position 1 with the pump running.
2) Set the flow rate to the "Set Flow" value given in cell D23 on the A, B, C, D, or X

worksheet. This is the temperature corrected flow rate in liters per minute (lpm) for module 1A. It should be 23 ± 1 lpm unless the temperature is more than 40 °C or lower than 0 °C. Check the "Device Nominal (23lpm)" value on the Site and Device Data section of the Site and Device Data sheet (cell C12). The number should be three significant digits. Once the flow rate is set to the temperature corrected value, the value read on the Magnehelic should be close to the Device Nominal. The value read on the Magnehelic will be entered into cell E20. Check the "Q Mag" box (cell B26). The value in this cell should be around 23.0 lpm. This is the actual flow being measured and will be different from the temperature corrected flow rate unless the temperature is exactly 20 °C. Turn the valve of the module until the flow rate displayed on the controller matches the temperature corrected flow rate. Record the Magnehelic, Pressure/ORI and Flow/CYC values.

3) Cycle through the other three positions, recording the magnehelic reading and the Pressure/ORI and Flow/CYC values for each.

4) If the R^2 value is reasonable, i.e. close to "1.000" (cells H29 and J29), check the "ORI Error" (cells E26 to E29) and "CYC Error" (cells F26 to F29), generated by comparing the calculated flow rates from the Pressure/ORI and Flow/CYC to the flow calculated from the measured Magnehelic values (cells B26 to B29). If the values differ significantly (> 5%) recheck the Magnehelic, Pressure/ORI, and Flow/CYC values. If the errors are 5% or below, the values are acceptable. Also compare the equation slope and intercept for both the ORI and CYC to the universal values. If they are not similar, determine the cause of the difference in nominal values. Some possible explanations are new electronics boxes and/or electronic drift in transducers. If you cannot determine the cause, please call the field manager for assistance. It may help to switch electronic boxes and try to calibrate again to see if the source of the problem is the particular electronic box.

5) Move on to the 2B module. Repeat the steps listed above, making sure the controller displayed flow rate value on the screen matches the value in cell D23. This will be around 23.0 liters per minute. Record all of the values and compare them to the universal constant values. Then, proceed with module 3C in the same manner.

6) Module 4D is slightly different. The probe must be modified in order to fit properly. For step-by-step instructions on how to modify the probe, please see TI 226C. Also, the "Set Flow" value will be much different than the previous three modules. Find this flow value in cell D23 on worksheet "D". Make sure that it has a flow rate of around 16.9 lpm. Finally, only Pressure/ORI values are taken during 4D module calibrations, as the Flow/CYC sensor is not used in the 4D mod. All other procedures, such as comparing values to the previous year's values, still apply.

7) Record the new temperature values from the keypad display. Also make sure the "Vacuum/MxORI" and "Zero Flow" values were recorded during calibration. Currently the "Zero Flow" values will be roughly 14.7 psi at sea level for the Pres/ORI, and 0.00 for the Flow/CYC. Zero Flow values can be measured by taking the Pres/ORI and Flow/CYC sensors with the pump off and solenoid open, accessed from the Flow Adjustment menu option.

8) Record the time of flow adjustment in the flow check/flow adjustment spreadsheet.

9.3.7 Post Flow Adjustment Procedures and Checks

1) Update the date and time on the controller if necessary. Do this by pressing **Menu** from the home screen, then selecting **Settings**. Ensure that the GMT is set correctly by selecting **Time Zone** from the same menu.

2) Verify that all of the site configuration parameters are correct. From the Home Screen, go to **Menu**, then **Advanced Menu** and enter code **1123**. The Site Config menu option will be the first option. There are several parameters to adjust within the Advanced Menu. Some of them are as follows:

   - Site: The four-letter site name followed by a number.
   - "UC Code": This is a four-digit number that is used as the site's inventory number. In most cases, it should match the last four digits under the barcode in the interior of the 1A module case.
   - SD Card: This will configure whether the controller asks for a new memory card every week (bag) or every three weeks (box).
   - Edit Schedule: Each site will be either "2-3-2" or a "3-2-2." If the blue box has a yellow sticker with the site code printed on it, the site is a "2-3-2." If the blue box has a green sticker with the site code printed on it, it is a "3-2-2." The IMPROVE calendar lists which week bag should be used on each Tuesday according to blue box schedule.
   - Server Settings: Enable or disable remote backup of flow data.

3) Verify that the advanced site configuration parameters are correct. From the Home screen go to **Menu**, then **Advanced Menu** and enter code **9051**. The Maintenance Menu will come up and some of the options are as follows:

   - Unlock Controller: This can be used in special cases to unlock the controller without performing the filter readings procedure.
   - Elapsed Times: This can be used to edit the amount of the time the controller reports sampling for. This feature is used by maintenance technicians to correct the elapsed sample times due to interruptions resulting from maintenance.
   - Edit Constants: This can be used to edit the calibration constants. After 2018, this should no longer be necessary, and operator should never use this menu option.
   - Config Modules: This screen will display one module per page and lists whether the module is online, what module type it is (1A, 2B, 3C, or 4D) and gives the option to edit the calibration constants.

4) Update operator initials if needed. Do this by pressing **Menu** from the Home Screen, then **Settings**, and **Operator Initials**.

5) Install the current sampling set of cartridges and run through Final/Initial readings by

pressing **Filter Readings** from the Home Screen. Correct initial readings for any samples that have not yet run.

6) Fill out or update the site data sheet and note any equipment changes.
7) Leave any pertinent documents for operators either inside the controller or in the blue box if the documents cannot be given directly to the operator.
8) Make sure all equipment inventory numbers have been recorded. These include inventory numbers for:
    - Pumps
    - Controller/ Controller Configuration
    - Network device/ Network Configuration
    - Modules
    - Electronic boxes
    - Relay boxes
    - Denuder
9) Make sure the pump rebuild dates have been recorded.
10) Record breaker amperage and quantity.
11) Label all equipment with colored tape to make it easy for the operator to troubleshoot.
12) Tape 1A, 2B, and 3C Tee plugs to the Tees and add 1A, 2B, 3C, and 4D stack labels to the stacks. Use the appropriate color of tape (red for 1A, yellow for 2B, green for 3C, blue for 4D, or orange for 5X modules) for each module.
13) Take pictures of the following:
    - Eight inward views while standing approximately 30 yards away from the site; take pictures of the site looking N, NE, E, SE, S, SW, W, and NW
    - Four outward views while standing with back against the site and looking towards N, E, S, W
    - All of the modules
    - Pumps and relay boxes
    - Source of power for controller and relay boxes (e.g., A/C outlets, power strip)
    - Breaker, from a distance and up close
    - Roof
    - Stacks (include inlets)
    - Sampler Overview
14) Call lab for any necessary equipment.

10. REFERENCES

UCD SOP #226: Attachment 1, "Maintenance Packing Lists"

UCD SOP #226: Attachment 2, "Maintenance Checklist"

UCD SOP #201: Sampler Maintenance by Site Operators

TI 226B, "Audit"

TI 226C, "Calibration"

TI 226D, "Denuders"

TI 226E, "Leak Check"

TI 226B: Flow Check

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this TI is to describe the flow check procedures used during field maintenance for all IMPROVE network sites.

2. SUMMARY OF THE METHOD

The field technician performs a flow check of the modules during field maintenance to test current flow rates and equations in order to determine if there has been any drift since the last maintenance visit. Flow rate values for each module are checked and recorded.

3. CAUTIONS

Make sure that the magnehelic is set to zero when vertical and that the tubing for the device is straight and not kinked before beginning the flow check.

4. EQUIPMENT AND SUPPLIES

A black, hard-cased flow check kit should contain the following:

- Magnehelic and Probe
- One flow check cartridge for each module being checked, four maximum
- One 5/32" hex key
- NIST-certified thermometer

The field technician should also have a prepared, site-specific flow check sheet.

5. PROCEDURES

5.1 Preparing the Modules and Controller for the Flow Check

1) Open the controller door and press the **Home** button if the display is not on main screen, which will bring up the main menu.
2) Remove the sampling cartridges from the modules. Make sure that final readings have already been taken.
3) Insert each flow check cartridge into its corresponding module.
4) Access pump and solenoid control through the Flow Adjustment option of the Maintenance Menu. From the Home Screen, Press Menu, Advanced Menu, enter code 9051, press Submit, press More and Flow Adjustment will be the second menu option.

5.2 Recording Temperature, Max Orifice, and Zero Values

1) In the flow check device case, there will be a NIST-certified thermometer. Please take the thermometer out of the case and place it in the shade next to the 3C module. Turn the power switch to the "On" position and the unit switch to "°C." Disconnect the temperature probe from the 3C module and place the tip of the probe next to the

thermometer. Allow the thermometer to equilibrate for approximately five to ten minutes.

2) To take the temperature reading from the probe, look at the temperature displayed in the upper right corner of the Home Screen. Record this value in cell C16 of the sheet titled "Site and Device Data". Then, record the value reported by the thermometer in cell C15.
3) To take Vac/Max Orifice (or MxORI) values, enter the Flow Adjustment Mode. For each module turn on its pump and no solenoids. Record the values for each module in cell B8 for each module specific sheet.
4) To take zero values for the Pres/ORI and Flow/CYC of each module, go to the Flow Adjustment menu option. Note that if the system was sampling upon arrival, the pump must be stopped before measuring zero flows. With the pump off and at least one solenoid open, the controller display will show the zero values for the 1A module. Enter the CYC Zero and ORI zero values in cells B9 and B10, respectively, of the 1A module sheet. Navigate through each module by pressing the > button and record the values in the appropriate sheets and cells. When finished with the last module, press the **Home** button to exit the Flow Adjustment Menu.

5.3 Preparing the 1A Module and Magnehelic

1) Place the magnehelic on the inside of the module 1A door. Note that it is digital so orientation doesn't matter. The magnehelic has a magnet on the back, so it will stay attached. Make sure that the magnehelic reads "0.000," when turned on. If not, hold the "Zero" button to reset the value to zero.
2) Inside the 1A module, locate the stack plug and the black plastic cap. Remove the cap by pushing down on it from the top, and remove the plug by pulling down on the brass fitting.
3) Place the probe into the Tee. Do this by pushing the probe (hose end down) through the bottom of the module and up into the Tee until the probe bottoms out.
4) On a windy day, the magnehelic reading may fluctuate. To keep the reading stable, use the PVC cylinder included in the Flow Check Kit. If no PVC cylinder is included, wrap the open end of the Tygon tubing with a piece of laboratory wipe, making sure not to block or restrict any of the holes on the probe or pressure hoses.

Figure 1. Removing the plastic cap and stack plug.

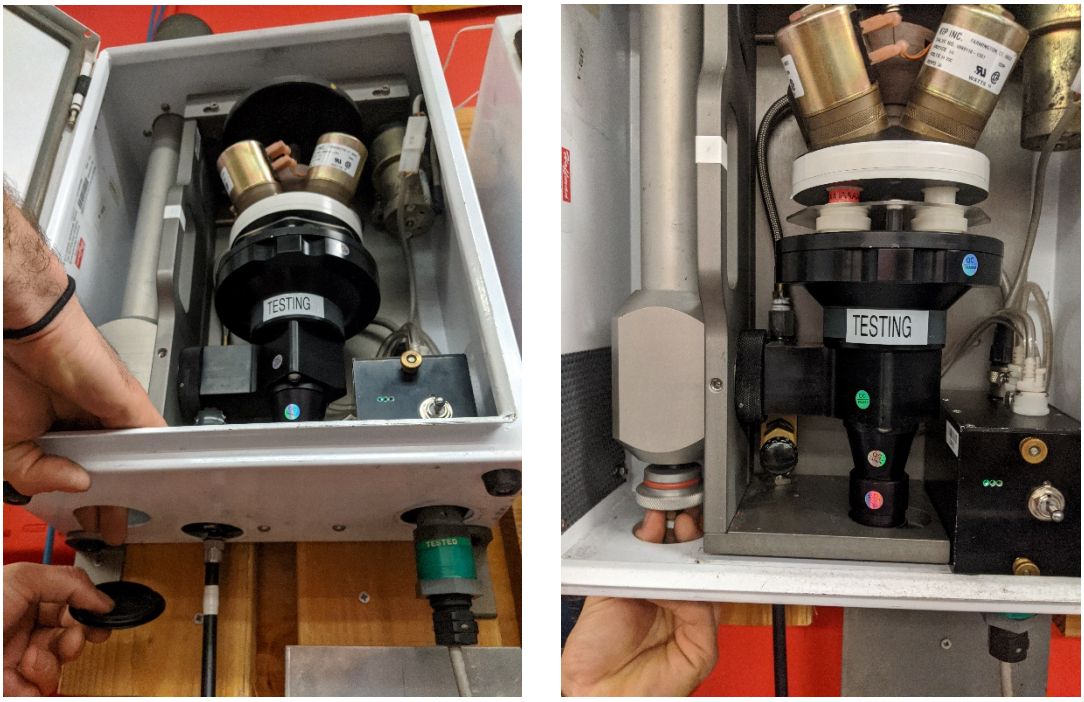


Figure 2. Inserting the probe into the tee.

Figure 3. Attaching the PVC dampener.

5.4 Begin the Flow Check

1) Return to the controller's display. From the Advanced Menu enter **9051** and press **Submit**. Press **More** and then **Flow Adjustment**.
2) The module 1A sensor data will be displayed. Turn on solenoid 1 by pressing **S1: Off**. Turn the pump on by pressing **Pump: Off**. The magnehelic pressure gauge will move from the 0" H2O position to a value greater than 0.

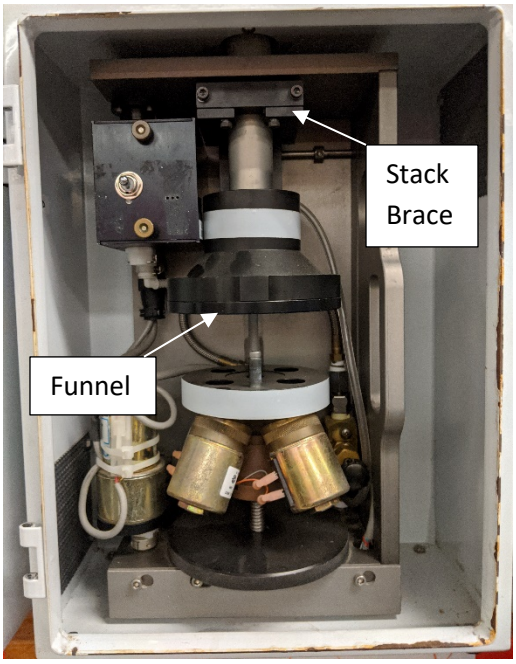
5.5 Filling in the Flow Check Sheet

1) Check the magnehelic value. Enter the displayed number into cell C8 of the flow check sheet, making sure to place a decimal before the number.
2) Look at the controller display. It will show two values for position 1, the Flow/Cyclone (CYC) and the Pres/Orifice (ORI) sensor values. Enter these in cells D8 and E8, respectively. If either of the values is unstable, note the full range of values in the comments section on the bottom left of the flow check sheet.
3) Once these values are recorded, press the **S1: On** button and then the **S2: Off** button to move to the second position of the flow check cartridge. The buttons should now read "S1: Off" and "S2: On." Record the magnehelic and CYC/ORI values in cells D9-E9. Repeat the previous steps 1 and 2 for each of the four positions, making sure the correct solenoid is open and record the values in the appropriate cells.
4) Repeat steps 1-3 for modules 2B and 3C.

5.6 Preparing Module 4D

1) In order to flow check module 4D, first raise the stack to accommodate the flow check probe. There are two things that need to be loosened before the stack can be raised. First, loosen the locking collar on top of the module by turning it counterclockwise. Then, take the 5/32" hex key and loosen the four screws of the 4D brace. Do not remove the screws.
2) Slide the stack up approximately four inches or until it is above the 4D brace. After moving the stack, retighten the locking collar to temporarily secure the stack.

Figure 4. Module 4D



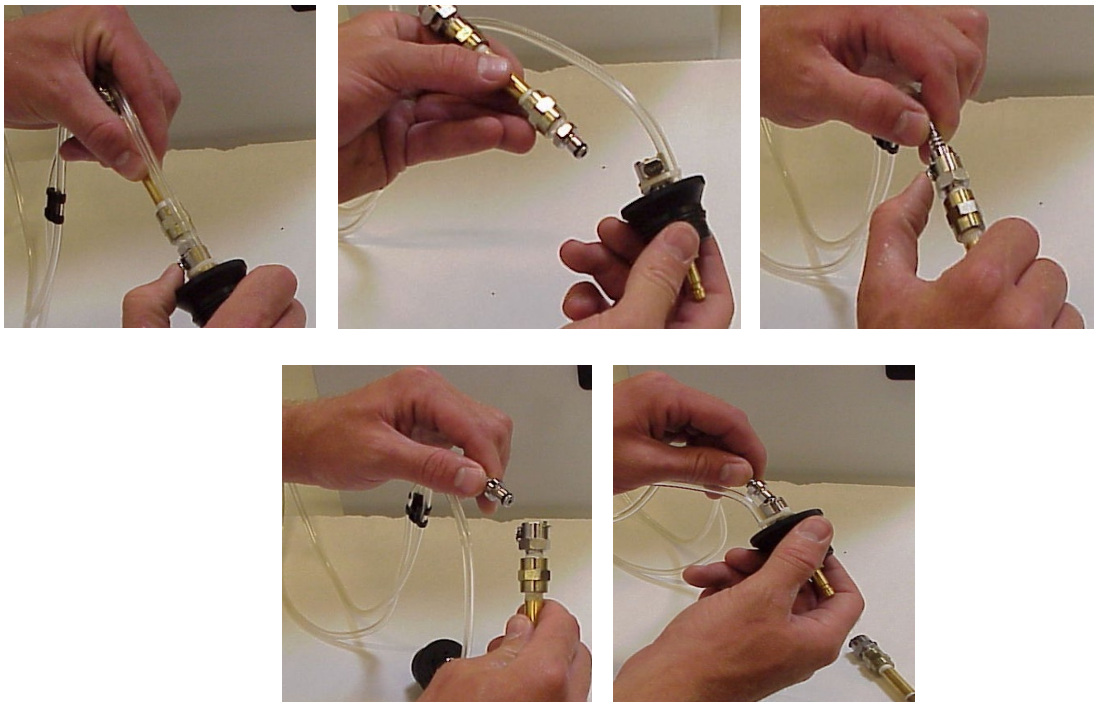
5.7 Preparing the Magnehelic Probe

In order for the probe to fit into the funnel of the 4D module, it is necessary to make two modifications to the probe itself:

- First, locate the spring-loaded coupler, which is between the probe and the probe plug. Push this coupler's outer sleeve down (toward the hose). This will release the probe plug.
- Second, locate the 3-inch brass extender bar, which is attached via quick connects. To remove this extender bar, disengage the quick connects by pushing on the buttons and gently pulling the bar away. After removing the extender bar, attach the quick-connect fitting on the hose to the probe quick-connect.

Figure 5. Releasing the probe plug

Figure 6. Modifying the probe.



5.8 Conducting the Flow Check on Module 4D

1) Place the probe into the top of the funnel (where the stack was previously) and gently push down until it bottoms out.
2) With the flow check probe in the funnel of the 4D module, the 4D module flow check can now be completed. Repeat the steps in section 5.4 for the 4D module.

Figure 7. Inserting the flow check probe into the 4D Module

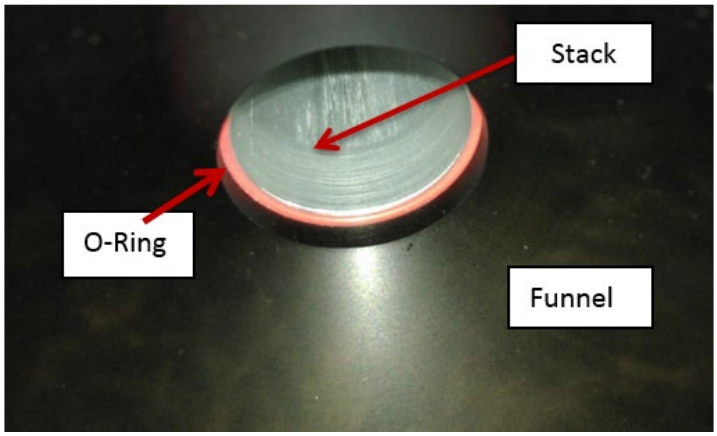
5.9 Re-installing the 4D Stack

1) Remove the 4D funnel's bottom lid. Using both hands with thumbs on the recessed channels of the funnel, pull downwards to separate the bottom lid from the rest of the funnel (Figure 8). Sometimes it is necessary to use a soft mallet to gently tap the bottom lid to separate the two pieces.

Figure 8. Removing the bottom lid of 4D Module funnel

2) Gently lower the stack back to its original position, making sure that the stack is fully seated into the black funnel. It should rest on an orange (or black) O-ring as in Figure 9.
3) While the 4D funnel's bottom lid is still removed, verify that the 4D stack O-ring is securely in place and uniformly positioned between the silver stack and the retaining lip of the 4D funnel.

Figure 9. 4D O-Ring between stack and funnel.



4) Tighten the sleeve collar by turning it clockwise and then tighten the four screws on the 4D brace to secure the stack.
5) Replace the 4D funnel's bottom lid.
6) If the modules are not being flow adjusted, perform the following steps:
    - Double-check that all black plastic caps and stack plugs are in their proper position for modules 1A, 2B, and 3C.
    - Reassemble the magnehelic probe to its original configuration.
    - Place all of the flow check components back into the flow check kit.

- Reload the modules with the exposed sampling cartridges. If a sample change needs to be performed, do it now. Record final readings for all modules, install clean sampling cartridges, and take initial readings.

5.10 5X Modules

Some sites have a fifth module for collocated precision measurements, referred to as an X module or 5X. The X module is a duplicate of a 1A, 2B, 3C, or 4D module. The A, B, C, or D designation after the 5 determines what filter media and particle size is used for the 5X module. If there is fifth X module, present, determine what type of module it is and perform the flow check accordingly.

TI 226C: Flow Adjustment

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this TI is to describe the calibration procedures used during field maintenance for all IMPROVE network sites.

2. SUMMARY OF THE METHOD

The field technician performs a flow adjustment of the modules after completing a flow check and general cleaning of the equipment. The flow adjustment corrects current flow rates and equations in the event of any drift since the last maintenance visit due to equipment malfunction or new equipment installation.

3. CAUTIONS

Make sure the magnehelic is set to zero (while the dial is vertical) and that the tubing for the device is straight before beginning the flow adjustment.

4. EQUIPMENT AND SUPPLIES

A black, hard-cased audit kit should contain the following:

- Magnehelic and Probe
- One flow adjustment cartridge for each module, four total
- One 5/32" hex key
- NIST-certified thermometer

The field technician should also have a prepared, site-specific flow check/ flow adjustment sheet.

5. PROCEDURES

5.1 Preparing the Modules and Controller for the Flow Adjustment

1) Open the controller door and press the **Home** button, which will bring up the main menu.
2) Remove the sampling cartridges from the modules. Make sure that final readings have already been taken.
3) Insert each flow adjustment cartridge into its corresponding module.

5.2 Recording Temperature, Max Orifice, and Zero Values

1) In the flow check device case, there will be a NIST-certified thermometer. Please take the thermometer out of the case and place it in the shade next to the 3C module. Turn the power switch to the "On" position and the unit switch to "°C." Disconnect the temperature probe from the 3C module and place the tip of the probe next to the thermometer. Allow the thermometer to equilibrate for approximately ten minutes.
2) To take the temperature reading from the probe, record the temperature from the upper right corner of Home Screen. Record this value in cell C18 of the "Site and Device Data" sheet. Then, record the value reported by the thermometer in cell C17.
3) To take Vac/Max Orifice (or MxORI) values, access the Flow Adjustment Mode, as described previously, or use the Vacuum Test option from the Equipment Tests menu. All the pumps should turn on in Vacuum Test mode. If in Flow Adjustment mode, turn on the pump, and make sure all solenoids are off. After running for a few seconds, MxORI values will appear for each module. Record the values for each module in cell D20 for each module-specific sheet.
4) To take zero values for the Flow/CYC and Pres/ORI of each module, access the Flow Adjustment Mode, open a single solenoid and make sure the pump is off. Note that if the system was sampling upon arrival, the pump will be running and will need to be turned off by pressing **Pump: On** so that it will read "Pump: Off". The controller display will show the zero values for the 1A module. Enter the values in cells D21 and D22 of the 1A module sheet. Cycle through the modules by pressing > and record the values in the appropriate sheets and cells, making sure that no pumps are

running during the measurement. When finished with the last module, press the **Home** button to exit the Flow Adjustment Menu.

5.3 Preparing the 1A Module and Magnehelic

1) Place the magnehelic on the inside of the module 1A door. Note that the magnehelic is digital so orientation doesn't matter. Make sure the magnehelic reads "0.000" when on. If not, hold the "Zero" button on the magnehelic until it reads zero. The magnehelic has a magnet on the back, so it will stay attached to the door. If it is windy out, it is necessary to try to shelter the ambient pressure hose from the wind, without plugging it. This is best accomplished by attaching the ambient hose end to the PVC dampener included in the kit (Figure 2).
2) Inside the 1A module, locate the stack plug and the black plastic cap. Remove the cap by pushing down on it from the top, and remove the plug by pulling down on the brass fitting.
3) Place the probe into the Tee. Do this by pushing the probe (hose end down) through the bottom of the module and up into the Tee until the probe bottoms out.
4) On a windy day, the magnehelic reading may fluctuate. Remedy this by attaching the ambient hose end to the PVC dampener included in the kit (Figure 2) as mentioned above.

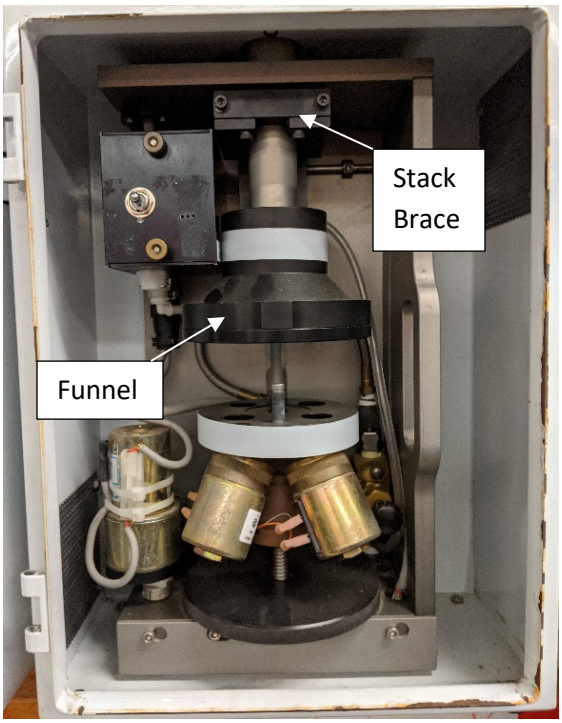
Figure 1. Removing the plastic cap and stack plug and inserting the probe into the tee.

Figure 2. Attaching the PVC dampener.

5.4 Preparing Module 4D

1) In order to flow adjust module 4D, first raise the stack to accommodate the flow check probe. There are two things that need to be loosened before the stack can be raised. First, loosen the locking collar on top of the module by turning it counterclockwise. Then, take the 5/32" hex key and loosen the four screws of the 4D brace. Do not remove the screws.
2) Slide the stack up approximately four inches or until it is above the 4D brace. After moving the stack, retighten the locking collar to temporarily secure the stack.

Figure 3. Module 4D.



5.5 Beginning the Flow Adjustment

1) Return to the controller's display. From the Home Screen, press the **Menu** button, then **Advanced Menu**, enter code **9051**, press **Submit** press the **More** button, and press **Flow Adjustment**.
2) Note that zero flows are no longer set for each module. The zero flow measurements are actual pressure measurements and reflect environmental conditions. The Flow/CYC sensor should be very close to zero (± 0.02) and the Pres/ORI sensor will be around 14.7 psi at sea level and reducing linearly with elevation.
3) The flow adjustment cartridge has a filter in its first position, and physical restrictions of increasing resistance in each consecutive position. Open the first solenoid by pressing **S1: Off** so that it reads "S1: On". Turn on the pump by pressing **Pump: Off** so that it reads "Pump: On".

5.6 Filling in the Flow Adjustment Sheet

1) The display will show two values (CYC and ORI). The magnehelic will indicate a value as well. Look at the number in cell D23 ("Set Flow"). If there is no number listed, enter the device constants into cells C10 and C11 of the "Site and Device Data" sheet (which are located on the flow check device case) and a number should be generated. The number in cell D23 will be around 23.0 LPM, depending on temperature. This will be the value that you will adjust the flow rate to, as displayed

by the controller screen. To achieve this flow rate, manipulate the valve located at the bottom center of the module (use the black knob on the needle valve, left of the cyclone, facing outward from the module) until the controller displayed flow rate value (to the right of the CYC pressure reading measured in " H_2O matches that of the value in D23. Record the value reported by the magnehelic for that position in cell E20.

2) Look at the controller display. It will show two values for position #1, the Cyclone (CYC) and the Orifice (ORI). Enter these in cells F20 and G20, respectively. If either of the values is unstable, note the full range of values in the comments section on the bottom left of the calibration sheet.

3) Once these values are recorded, press the **S2: Off** and **S1: On** button to move to the second position of the calibration cartridge and close the first solenoid. The buttons should read "S1: Off" and "S2: On". Record the magnehelic and CYC/ORI values in cells F21 and G21. Repeat the previous steps for positions #3 and #4, recording the values in the appropriate cells.

4) Repeat steps 1-3 for all four positions for modules 2B and 3C.

5.7 Preparing the Magnehelic Probe

In order for the probe to fit into the funnel of the 4D module, it is necessary to make two modifications to the probe itself:

- First, locate the spring-loaded coupler, which is between the probe and the probe plug. Push this coupler's outer sleeve down (toward the hose). This will release the probe plug.
- Secondly, locate the 3-inch brass extender bar, which is attached via quick connects. To remove this extender bar, disengage the quick connects by pushing on the buttons and gently pulling the bar away. After removing the extender bar, attach the quick-connect fitting on the hose to the probe quick-connect.

Figure 4. Releasing the probe plug.

Figure 5. Modifying the probe.

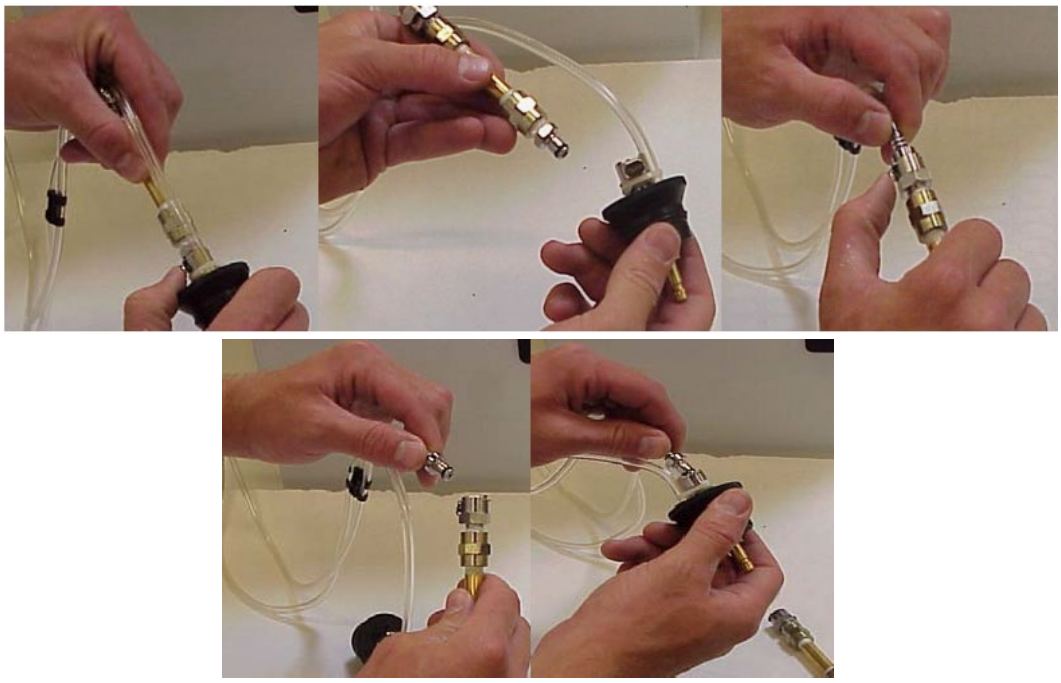
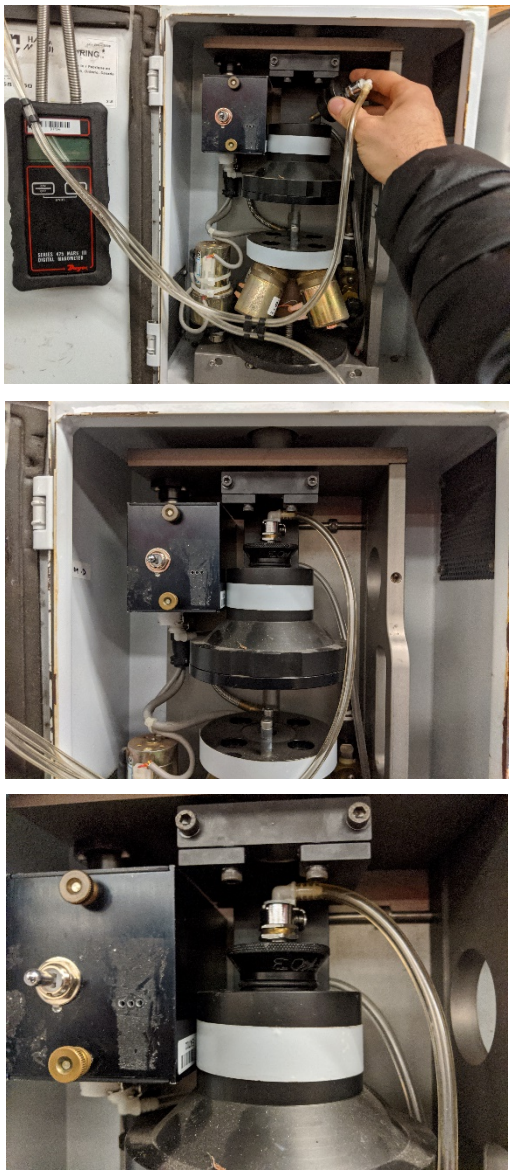


Figure 6. Placing the probe in Module 4D.



5.8 Flow Adjusting Module 4D

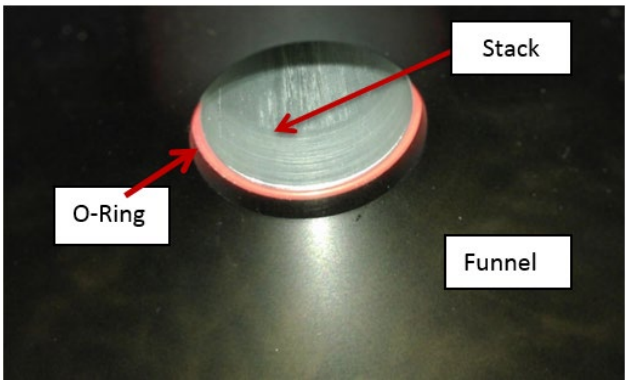
1) Place the probe into the top of the funnel (where the stack was previously) and gently push down until it bottoms out.
2) With the flow adjustment probe in the funnel of the 4D module, the 4D module flow adjustment can now be completed. Repeat the steps in 5.4 for the 4D module with a couple of exceptions. The number listed in cell D23 ("Set Flow") will be different than the one used for the previous modules. This is because 4D modules run at a different flow rate. The value in cell D23 should be around 16.9 LPM. The 4D module does not have a functioning CYC, so only the magnehelic and orifice values need to be recorded for each position.

5.9 Re-installing the 4D Stack

1) Remove the 4D funnel's bottom lid. Using both hands with thumbs on the recessed channels of the funnel, pull downwards to separate the bottom lid from the rest of the funnel (Figure 7). Sometimes it is necessary to use a soft mallet to gently tap the bottom lid to separate the two pieces.
2) Gently lower the stack back to its original position, making sure that the stack is fully seated into the black funnel. It should rest on an orange O-ring as shown in Figure 8.
3) While the 4D funnel's bottom lid is still removed, verify that the 4D stack O-ring is securely in place and uniformly positioned between the silver stack and the retaining lip of the 4D funnel.
4) Tighten the sleeve collar by turning it clockwise and then tighten the four screws on the 4D brace to secure the stack.
5) Replace the 4D funnel's bottom lid.
6) Perform the following steps once flow adjustment is complete:
    - Double-check that all black plastic caps and stack tee plugs are in their proper position for modules 1A, 2B, and 3C.
    - Reassemble the magnehelic probe to its original configuration.
    - Place all of the flow adjustment components back into the flow check kit.
    - Reload the modules with the exposed sampling cartridges. If a sample change needs to be performed, do it now. Record exposed (final) readings for all modules, install clean sampling cartridges, and take clean (initial) readings.

Figure 7. Removing the bottom lid of Module 4D.

Figure 8. 4D O-Ring between stack and funnel.



5.10 5X Modules

Some sites have a fifth module for collocated precision measurements, called an X or 5X Module. The X is a duplicate of an A, B, C, or D module. If there is an X module present, determine what type of module it is and perform the flow adjustment accordingly.

TI 226D Denuders

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this technical instruction (TI) is to describe the function of the denuders used in 2B modules and to detail how they are cleaned and coated for reuse after returning from the field.

2. SUMMARY OF THE METHOD

Denuders are used in 2B modules to remove nitric acid vapor from the air before it binds to the nylon filter. All denuders are assigned an inventory number for record-keeping. Denuders stay in B modules for approximately one to two years and are switched out with a fresh one during field maintenance. The “dirty” denuders are brought back to the Air Quality Research Center shop, where they are cleaned and coated. The denuders are then ready to be sent out to another site.

3. DEFINITIONS

Denuder: a series of concentric aluminum tubes that is placed within the 2B module stack at

sampling sites. The denuder serves to remove nitric acid vapor from the air stream before it binds to the nylon filter. The goal is to collect nitrate particles (which affect visibility) and not nitric acid (which does not).

4. HEALTH AND SAFETY

Always be cautious when handling chemicals. Wear gloves and safety goggles when preparing the solutions to clean and coat the denuders.

5. PERSONNEL QUALIFICATIONS

Field technicians and trained shop assistants are responsible for cleaning and coating denuders in preparation for them to be sent out into the field.

6. EQUIPMENT AND SUPPLIES

Supplies for Cleaning Denuders:

- Household grade ammonia
- Alconox glass cleaner
- Balance
- 1L graduated cylinder
- 2L Flask
- Ultrasonic bath
- Deionized water
- Denuder drying bucket-rack
- Paper
- “Dirty” denuder bin
- “Clean” denuder bin
- Safety glasses and gloves

Supplies for Coating Denuders:

- 1L graduated cylinder
- Balance
- 2L flask
- 1L plastic bottle
- Deionized water
- Glycerol
- Sodium carbonate (Na2CO3)

- Paper
- "Coated" denuder bin

Miscellaneous Supplies:

- Computer
- Engraver

All of the necessary supplies can be found in the IMPROVE shop. The chemical materials are found with the cart of supplies, kept in the chem lab.

If any of the solution ingredients have run out, chemical supplies can be obtained in the Chem 149 storeroom. See the field manager or shop supervisor for the billing number, which is required for making purchases. Make sure to obtain a receipt for billing purposes. Sign and date the receipt and then submit it to the shop supervisor or field manager.

7. PROCEDURE

7.1 Assigning an Inventory Number

All denuders must be assigned an inventory number. The inventory number should be etched on either the top or the bottom end of the denuder. If a denuder does not have an inventory number, go into the denuder inventory file, find the next available sequential ID number, and assign it to the denuder. This inventory file can be found in the U:\ Drive. All denuder inventory numbers are in the format "D####." Use the engraver to inscribe the next sequential number onto the end of the denuder.

7.2 Updating the Inventory

A denuder is classified as being in one of four states: dirty, coated, scrapped, or currently installed at a field site. If a denuder has just returned from the field, it is considered "dirty" and should be classified as such. To inventory a denuder, first pull up the denuder inventory on the shop computer. Sort according to denuder ID and find the line that corresponds to the last known location of the denuder. Insert a new line into the spreadsheet. Fill out the columns for the denuder ID, the site in which it was last installed, and the date it arrived in the shop. Change the status to "dirty" in the "Status" column. Clear the "Date Coated", "Site Sent To", and "Date Sent" columns.

7.3 Cleaning the Denuders

All "dirty" and brand-new denuders must be cleaned before being coated. "Dirty" denuders can be found in a designated bin.

7.3.1 Preparing and Using the Ultrasonic Bath

The ultrasonic bath is on the denuder cart, which is located directly outside of the AQRC shop, near the sink. Fill the bath with seven liters of deionized water. If unsure of where to locate the deionized water, ask shop personnel for assistance. Then, put on gloves and safety goggles. Take the graduated cylinder and add 10 mL of household grade ammonia. Pour the ammonia into the bath. Take a two-liter flask and fill it with one liter of

deionized water. Next, take a piece of paper and make it into a cup. Put the cup on the balance in the shop. Tare the balance, and then scoop 80g of Alconox glass cleaner into the cup. Pour the glass cleaner into the flask and stir until it dissolves. Add the solution to the bath.

Place up to eight denuders in the bath and run the bath for 30 minutes. If additional denuders need to be washed, the bath may be reused an additional three times for 32 denuders. If more than 32 denuders need to be cleaned, a new bath must be made. Discard all bath solution in the sink when the bath is complete.

7.3.2 Rinsing the Denuders

After the denuder bath is complete, remove the denuders promptly and rinse them thoroughly with the deionized water hose for several minutes. This can be done using the deionized water source outside AQRC shop. Allow as much water as possible to drain from the denuders, and then place them in the denuder drying bucket-rack. Allow them to dry overnight. Once the denuders are dry, place them in the "cleaned" denuder bucket. They are now ready to be coated.

7.4 Coating the Denuders

After being cleaned, denuders need to be completely immersed in a sodium carbonate (Na2CO3) solution. The coating solution enhances the ability of the denuder to remove nitric acid from the air stream.

7.4.1 Preparing the Solution

First, put on gloves and safety goggles. Locate the 2L flask, which is the vessel that the solution will be mixed in. Find the graduated cylinder and fill it with 100mL of deionized water. Then, measure out 30 mL of glycerol into the graduated cylinder, on top of the water. Pour the solution into the flask. Measure out another 900mL of deionized water into the graduated cylinder and add it to the solution.

Next, prepare to weigh the sodium carbonate. Use an empty weighing dish and place it on the balance. Tare the balance and then measure out 71g of sodium carbonate. Add it to the flask and agitate the solution until all of the sodium carbonate is dissolved. The solution is now prepared and should be placed into a 1L plastic bottle for storage.

7.4.2 Coating the Denuders

Obtain the graduated cylinder. Add 860mL of the sodium carbonate solution to the graduated cylinder. This level will ensure that the solution will not spill over once the denuder is placed into the cylinder. Take a clean denuder and submerge it into the solution. Pull the denuder out, turn it over, and submerge the other side. Remove the denuder from the solution and allow it to dry in the bucket-rack. Repeat this procedure for up to ten denuders. After ten denuders have been coated, the solution must be discarded. Take the solution to the sink and dilute it with hot water before pouring it down the drain. Allow the denuders to dry overnight and then place them in the "coated" denuder bin.

7.4.3 Updating the Inventory

Once the denuders are coated, their statuses must be updated in the inventory. Open the Access

inventory file and change the appropriate lines with the “Dirty” status in the “Status” column. Change the status to “Coated”. Fill in the date in the “Date Coated” column.

TI 226E: Leak Check

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this TI is to describe the procedure used to check the modules at IMPROVE sites for any vacuum leaks.

2. SUMMARY OF THE METHOD

Vacuum readings are taken from each pump and its corresponding module to ensure that the readings from each pump and module pair are similar to each other. Pump and module differences should not be greater than 2.0” Hg. If differences are too large, troubleshooting procedures are performed to determine where the leak is coming from.

3. CAUTIONS

After zeroing the vacuum gauge, make sure to close the switch on the gauge. If the tab is left open, glycerin will leak out.

4. EQUIPMENT AND SUPPLIES

Supplies for the vacuum kit:

- Adapter

- Probe
- Coupler
- Manifold plug
- Vacuum grease
- Vacuum gauge

Supplies for the maintenance spare parts kit:

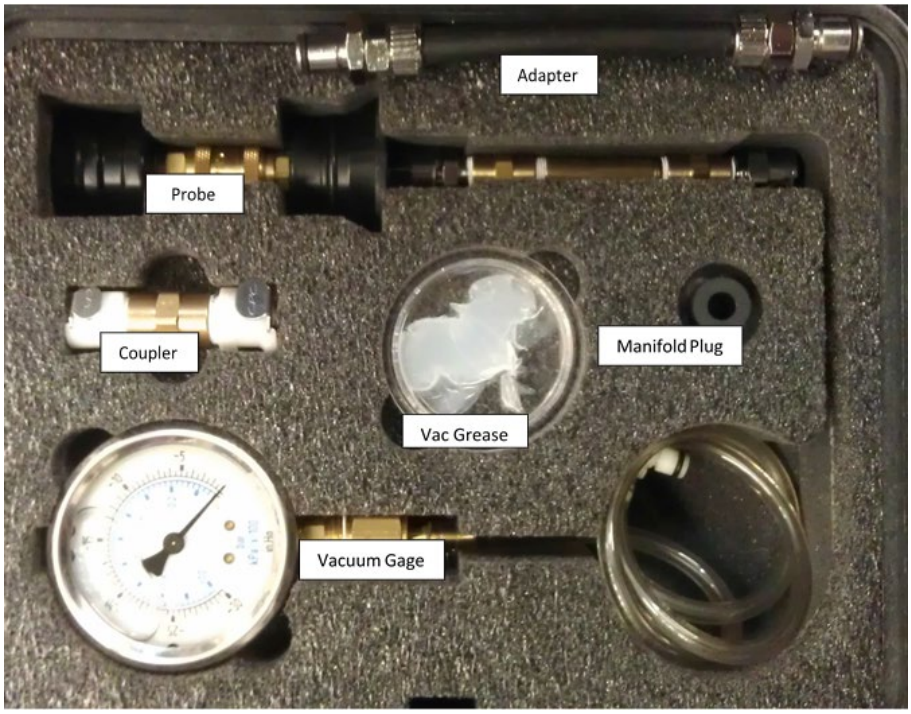
- Spare O-rings
- Cyclone
- Manifold
- Braided hose
- Valve

5. PROCEDURE

5.1 Leak Check at the Pump Hose

1) Take the vacuum gauge out of the vacuum kit. Zero the gauge by briefly lifting the yellow tab at the top to the "Open" position. After a few seconds, return the tab to the "closed" position to ensure that glycerin does not leak from the gauge.
2) Detach the pump hose from underneath the module and attach it to the large opening of the coupler. Attach the white plastic end of the vacuum gauge to the smaller end of the coupler.
3) From the Home Screen of the controller, press the **Menu** button, then **Advanced Menu** button, enter **9051**, press the **More** button, then **Flow Adjustment**.
4) Press the **Pump: Off** button to turn on the pump.
5) The needle on the pressure gauge will rise once the pump it is connected to is activated. Record this value in cell B20 of the flow check/calibration sheet or under "Pump ("Hg)" on the Leak Check form, whichever is being used. If the pump has trouble starting under vacuum, disconnect the coupler and reattach once the pump has started.
6) Press **Pump: On** to turn off the pump.
7) Disconnect the vacuum gauge, coupler, and pump hose. Restore the original configuration of the system.

Figure 1. Vacuum kit.



5.2 Leak Check at the Module

1) Open the module that needs to be leak checked and confirm it has a complete filter cartridge. Remove the black plastic cap from the bottom of the module. Then, remove the plug from the Tee, which is the rectangular part of the module located right above the black cap.

2) Insert the white, CPC end of the gauge into the end of the probe.

3) Fully insert the probe into the Tee. If the probe does not go into the Tee easily, try applying a very small amount of vacuum grease on the circumference of the top end of the probe. It is important to get the probe fully inserted into the Tee, as the reading on the vacuum gauge will not be accurate otherwise.

4) From Flow Adjustment mode press **S2: Off** to turn on the second solenoid. The solenoid used is not important, but at least one solenoid should be open to measure the vacuum pressure through the module.

5) Use **>** or **<** to cycle through to the module being tested. For this particular procedure, it does not matter what position is running.

6) The needle on the vacuum gauge should rise. Record the value in cell B21 of the module specific flow check/flow adjustment sheet or under “Mod (“Hg)” on the Leak Check form, whichever document is being used.

7) The difference between the pump and module readings should be less than two inches mercury (“Hg). If the difference is two or less, the leak check test is

complete. If the difference is greater than two, continue to the next section.

5.3 Leak Check at the Manifold

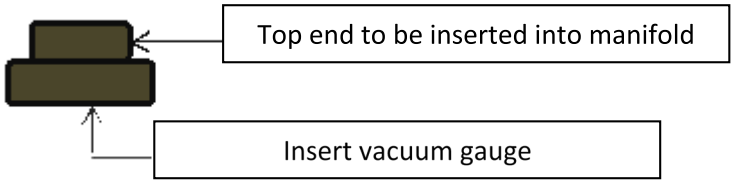
If the difference between the module and the pump is greater than two inches, this means that there may be a leak in one of five areas:

- Manifold
- Braided hose
- Valve
- Cyclone
- Cartridge

To narrow it down, perform the following test at the manifold:

1) Insert the end of the vacuum gauge (the white plastic barbed fitting) into the large circular end of the manifold plug (Figure 2):
2) Use the instructions listed in section 5.2 to go into **Flow Adjustment** mode. Use **>** and **<** to advance to the appropriate module being tested. Stay on position #1 for the module.
3) There are four holes on the underside of the manifold that normally encompass the tops of the filter cassettes. Insert the top end (smaller end) of the manifold plug into the bottom of the first hole, where the first filter cassette would normal sit.
4) The needle on the vacuum gauge should rise. Record this reading in the comments section of the flow check/flow adjustment sheet or under "Manifold Reading' on the Leak Check form, whichever is being used.
5) If the difference between the manifold and pump readings is less than two inches, the problem likely resides in the cyclone or the cartridge. Check to see if the cyclone is seated properly and that the connection between the cyclone and the Tee is straight. Check the cartridge to ensure that it is seated properly and that all of the cassettes have O-rings in the appropriate places. Remedy any issues and note the findings in the comments section on the flow check/calibration sheet or on the Leak Check form.
6) If the difference between the manifold and pump readings is more than two inches, a leak likely exists in the manifold, the braided hose, or the valve. To narrow it down even further, continue to the next section.

Figure 2. Manifold plug.



5.4 Leak Check at the Valve

To determine whether or not there is a leak in the valve, compare the vacuum from the top of the valve to the pump by performing the following procedure:

1) Find a short piece of pump hose (if included in the maintenance kit) or borrow a full pump hose from an alternate pump at the site.
2) Put the vacuum gauge in one end of the pump hose. Disconnect the braided hose from the valve and then connect the pump hose to the valve.
3) Use the instructions in section 5.2 to go into **Flow Adjustment** mode, open solenoid 1 by pressing **S1: Off** so that it reads "S1: On" on the appropriate module.
4) The needle on the vacuum gauge should rise. Record the value in the comments section of the flow check/calibration sheet or on the Leak Check form.
5) If the difference between the valve and pump readings is greater than 2" Hg, there is a leak from the valve. Replace the valve with a spare or remove and check fittings for integrity.
6) If the difference between the valve and pump readings is less than 2" Hg, the leak is likely coming from either the braided hose or the manifold. Replace them both with spare parts or determine faulty component and service it.

TI 226F Controller Repair

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this TI is to describe an overview of the procedures used to diagnose, repair, and ship controllers that are used at every site in the IMPROVE network. Detailed guides of repair procedures are now held within in-house documents. Controllers are diagnosed and repaired at the Air Quality Research Center shop, which is located in Jungerman Hall on the University of California, Davis campus.

2. SUMMARY OF THE METHOD

When an IMPROVE controller fails in the field, it is shipped to the Air Quality Research Center (AQRC) shop. At the shop, it is inventoried and a note is logged regarding the symptoms the controller had in the field. Field technicians or student shop assistants test the controller components in order to recreate and diagnose the problem(s). Once the problem has been determined, the controller is repaired and then tested again to confirm that it is fully functional. It is then ready to be shipped out to the next site in need of a controller.

3. CAUTIONS

Both of the controller power supplies need to be grounded to earth ground before the controller is worked on. If they are not, do not touch any part of the power supplies while the controller is uncovered and powered up in order to avoid an electrical shock.

4. PERSONNEL QUALIFICATIONS

Student shop assistants and field technicians work in the AQRC shop under the supervision of the field manager and shop manager. Each new student shop assistant and field technician receives one-on-one training on how to completely assemble/disassemble controllers. Each new employee also observes an experienced employee diagnose and repair a few controllers before he or she attempts one on their own. An experienced employee oversees the new employee for the first few controllers he or she repairs in order to correct any mistakes and to answer any questions.

5. EQUIPMENT AND SUPPLIES

The equipment and supplies for each controller repair vary significantly depending on what issues the controller has. Thus, the necessary equipment and supplies will be described in each section.

6. PROCEDURES

6.1 Diagnosis of Controller Problems

An IMPROVE controller can be thought of as a sprinkler timer with a digital microcontroller and an SD card for data logging.

A timer module opens and closes solenoids and relays and records the data from the pressure sensors to the memory card. While this seems like a simple system, a myriad of problems can

and do occur with these units. In the best-case scenario, the problem can be recreated on the spot and isolated to one component, which is then replaced or reworked so that the controller can go back into service. Unfortunately, however, the process is typically not so straightforward.

6.1.1 Receiving, Inventorying, and Documenting a Controller

Controllers must be checked in when they are received from the field. Locate the UPS shipping label on the box that the controller came in and note the sender's site code (five characters) and JIRA issue tracking number. Use this data to locate the issue reported through JIRA, the online issue-tracking database used by AQRC.

Open up the box and remove the controller. Note any damage to the controller that may have occurred during shipping. Discard the box by breaking it down and dispose of it in the cardboard recycling bin, which is located outside at the southwest corner of Jungerman Hall. If the foam inserts in the box are intact, place them with the other shipping supplies. If they cannot be reused, throw them away.

Each controller has an assigned inventory number in order to keep track of where it has been and what problems it has had in the past. Inventory numbers are five characters long. Each inventory number begins with the letter "C" and is followed by four digits. The first digit signifies the version of the equipment and the next three digits are a sequential count of controllers. Inventory numbers can be found on the inside of the controller door or on the inside of the case of the left side. Locate the inventory number for the controller and open the Microsoft Access controller inventory sheet located in U:\IMPROVE_Field\Shop and Operator Resources\Equipment Inventory. Find the entry for the controller. Follow the workflow dictated by the inventory application. If there is a discrepancy, notify a supervisor. The simplest way to determine why the controller was removed from the field is to check the JIRA issue number in the online issue-tracking database, JIRA. Either type the four-letter site code or unique JIRA issue number, the four-letter site code followed by a number, (SITE-99 for example) that was pulled from the controller box shipping label. A new page should load, which should display all of the recorded problems for the site.

Close to the top (where the most recent entries are located), there should be both an equipment request issue type entry indicating when a replacement controller was sent to the site, as well as a parent entry the subtask belongs to, detailing the problem that prompted the equipment replacement. Summarize the problems associated with the controller in the comment field of the inventory application. The Microsoft Access inventory database auto-saves all data entered, and allows simultaneous use by multiple users.

Next, advance the JIRA equipment request through its workflow. This means advancing the issue from "Pending Equipment Return" to "Completed" by clicking **Equipment Checked In**. This will prompt the user to enter "Checked In By", "Check In Date", "Return Inventory", and "Comments" if applicable. JIRA workflow is shown in Appendix 7.2.1.

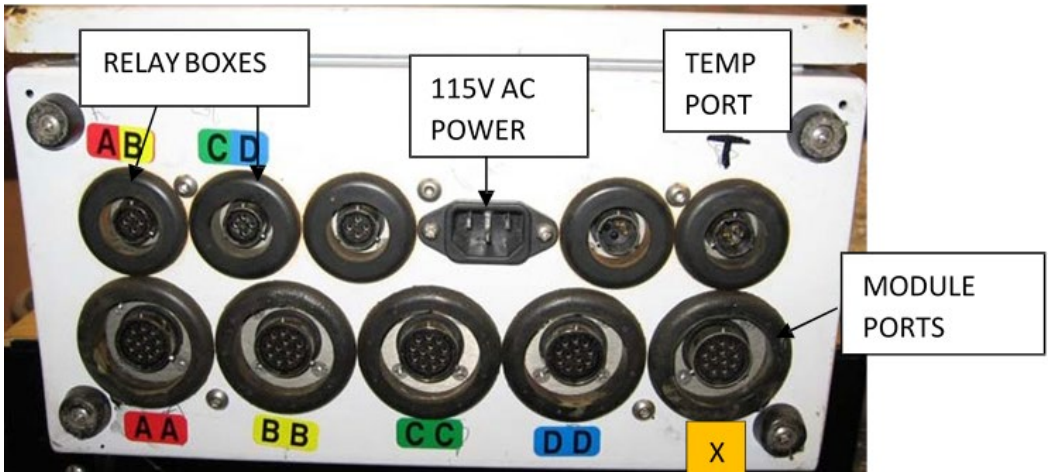
Now that the controller has been checked in, the next step is to test the controller in order to diagnose the exact cause of the problem and to check for any additional problems not detailed in the JIRA issue. Often the diagnosis is time sensitive. For example, if the checked in controller works fine, typically that means a different component will need to be sent to fix the problem in the field. If this is the case, the controller should be tested upon receiving.

To proceed with diagnosis, continue on to the next section. If the controller is only being checked in, place it on the "To Be Repaired" shelves in the AQRC shop.

6.1.2 Controller Set-Up

Set up the controller, five modules, three relay boxes, five pumps, and a temperature probe along with all of the corresponding cables. Make sure that all components are properly installed in order to accurately model a working sampling unit. The controller should have five module cables, which should be plugged into the 1A (Red), 2B (Yellow), 3C (Green), 4D (Blue), and 5X (Orange) ports, respectively. Relay box cables should be plugged into the 1A/2B port (Red/Yellow), the 3C/4D port (Green/Blue), and the 5X port (Orange) (see Figure 1). A temperature probe should be plugged into the temperature probe port. Do not plug in the controller's power cord yet. Note that when testing the 5X port, the controller must first be configured for a 5X module (see section 6.4.2.1 for details).

Figure 1. Port layout.



Each module should be operational and attached to a vacuum pump via a pump hose. The five pumps should be plugged into the AC outlets of the relay boxes. Make sure that each pump is plugged into the correct relay box, as the pump and relay box should both correspond to the same module. The relay box power cords should be plugged into 115 Volt AC outlets.

Warning: before touching any of the boards, make sure to dissipate any static electricity by touching the steel controller case.

6.2 Controller Configuration

The following steps describe the specific information required to configure a controller for the site it is being shipped to.

In the V4 controller, the site configuration information is stored in a repository within the controller. To access and configure this repository, press the **Menu** button from the Home Screen, then **Advanced Menu**, and enter code **1123**. Press **Site Config**, then press the **pencil icon** next to row labeled "Site". Use the < and > arrows to move the cursor position. Use the ^ and **v** to change the character. Enter the four-letter site name with number. Press **Save**, then use

the **Back arrow** to navigate back to the Advanced Menu. Press the **Update Cfg File** button, and then press the **Replace config.ini** button.

The controller must now restart for settings to take effect. Press the **Back arrow**, then press **More**, press **More** again, then press **Shutdown**, **Restart**, and then **Yes**. When controller reboots, all the site configuration parameters should be correct.

6.3 Controller Shipping

6.3.1 Controller Preparation

1) Obtain a repaired controller with a completed "Controller Information" sheet. Fill out the shipping portion on the sheet (see Figure 15).

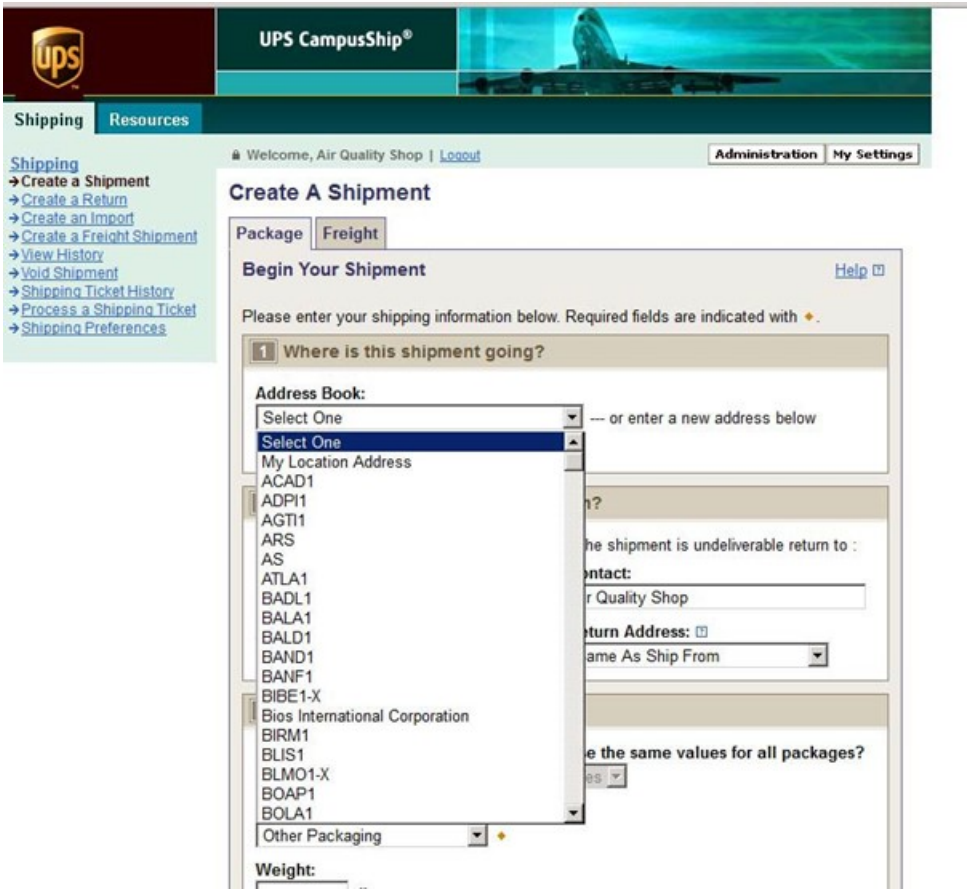
2) Fill out the "Controller Checklist" form for final inspection before shipping.

6.3.2 Creating the Shipping Label

1) Go to the UPS website and log in using the AQRC shop account.

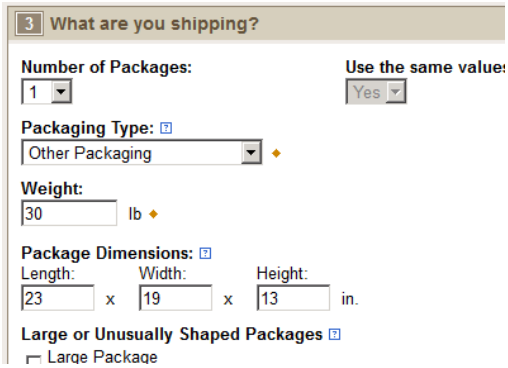
2) Click on the **Create a Shipment** option on the left-hand side and select the shipping site under the address book drop-down menu.

Figure 2. "Create a Shipment" on the UPS website.



Select **Other Packaging** under the "Packaging Type" drop-down menu and enter the appropriate weight and dimensions of the controller box (see Figure 4).

Figure 3. Shipment details.

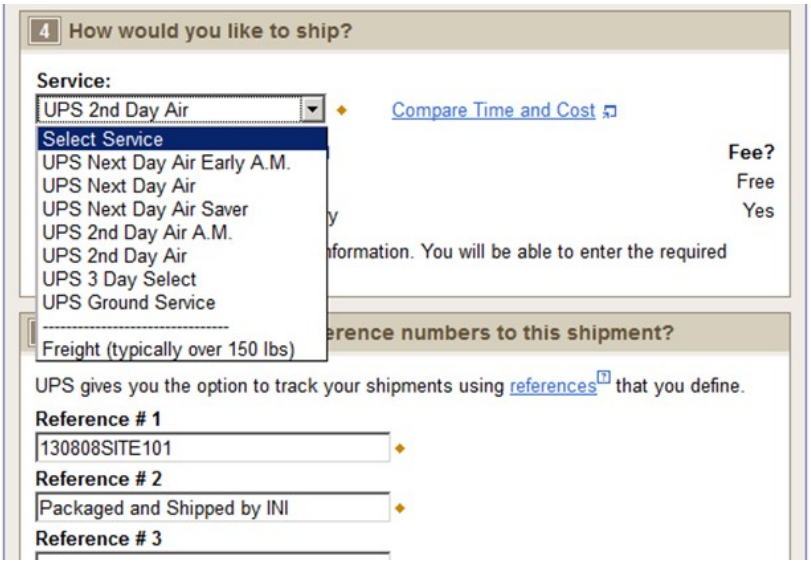


Select the appropriate shipping service and fill out "Reference" lines 1 and 2 in the following format:

Reference #1: JIRA issue number (No dash between site name and issue number)

Reference #2: Packaged and Shipped by XX (<= user initials)

Figure 4. "Select Service" and "References" on the UPS website.



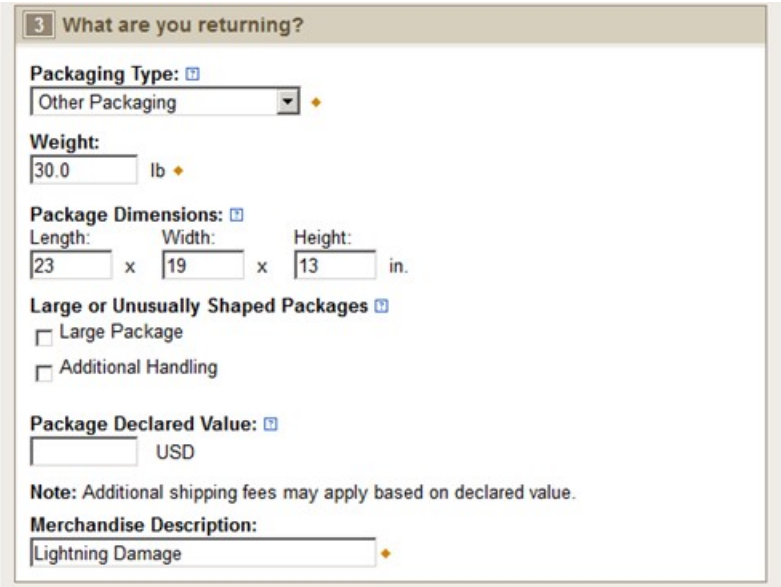
Once complete, review the shipment on the next page and select **Ship Now**.

6.3.3 Creating the Return Label Select "Create a Return Shipment"

Figure 5. "Create a Return Shipment" on the UPS website.

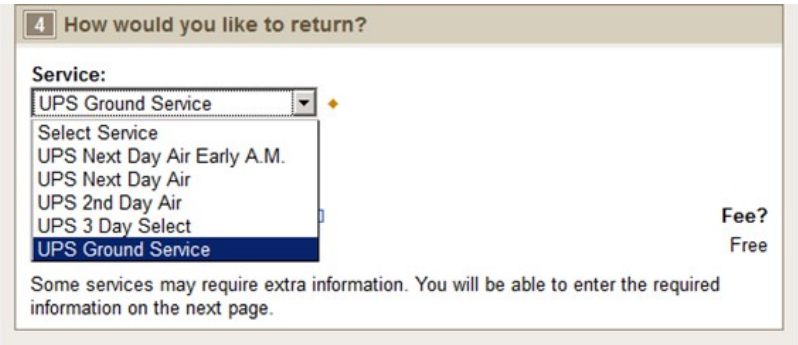
Under "Merchandise Description," enter a short description of the problem that the controller at the site has.

Figure 6. Return shipment details.



Select **Ground Service** for the return shipment and print the return shipping label.

Figure 7. Return shipment service.



6.3.4 Packaging the Controller

Place the controller in a shipping box (same size as for shipping modules) with special module protection foam inserts. Also, place the return label with the field letter instructions on how to replace and install a new controller in the box. Tape up controller box and leave the box in the shipping bay for UPS pickup.

Note: UPS pickup times are daily at around 4 pm.

6.3.5 Update the Inventory Data Base and JIRA

Go to the equipment inventory database located in "U:\IMPROVE_Field\Shop and Operator Resources\Equipment Inventory" and open the inventory application titled, "Field_Inventory_App.exe". Update the controller information for the controller being shipped using the **Ship Equipment** button, making sure to account for any equipment changes during repairs.

Edit the Equipment Request issue on the online issue-tracking JIRA software. The issue should be advanced through the workflow from either, "Open" or "In Progress" to "Pending Equipment Install" by selecting the **Equipment Shipped** button. The information necessary to fill out the form that comes up is date shipped, shipper's initials, inventory number, relevant UPS tracking numbers, and any applicable comments.

7. APPENDIX

7.1 Temperature Probe Construction/Repair

7.1.1 Equipment/Supplies

The following pieces of equipment are necessary for building and/or repairing temperature probes:

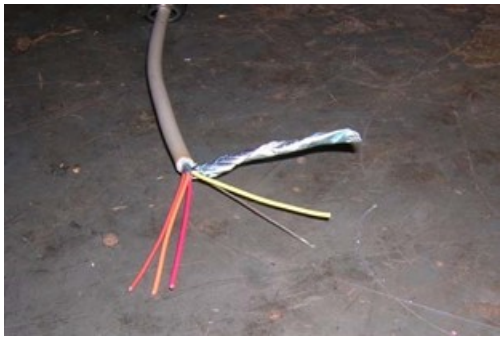
- Solder
- Soldering iron
- Small Allen wrench
- Wire cutters/strippers
- Crimpers
- Pin removal tool

7.1.2 Stripping Wires

First, check to see if the new wire is damaged. Next, choose any side to start with and strip the gray casing off about an inch from the end. Be careful not to cut through the encased wires.

If foil is still on the wires, remove it before continuing. There will be five wires remaining: one orange, one brown, one red, one yellow, and one bare. Cut off the yellow wire and the bare wire. Next, strip the orange, brown, and red wires about halfway. Twist the ends of the wires so that each of them is intact. Before continuing, ensure that the Tee plug and bottom plastic cap are on the wire because it will be difficult to fit them on later.

Figure 8. Exposed wiring.



7.1.3 Soldering the Thermistor

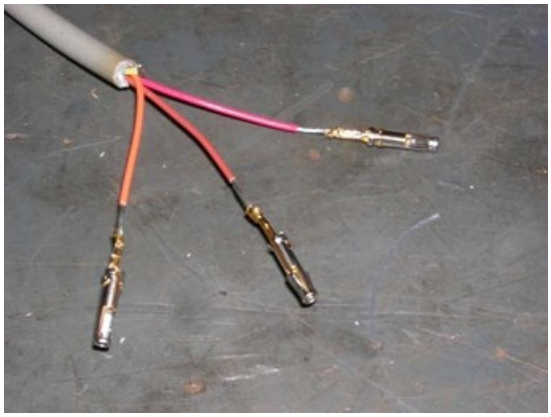
The next step will be to solder the temperature chip to the three wires that have been exposed (red, brown, and orange). The order in which they are soldered is very important as mixing wires can damage electrical components in the controller. With the flat face of the temperature chip facing 6 o'clock, solder the red wire to the left prong (1), the brown wire to the middle prong (2), and the orange wire to the right prong (3). All exposed wires must now be coated with liquid electrical tape, which can be found in the cabinet. None of the wires can touch each other. After one or two coats (depending on coverage), press all the wires together and put on a final coat of electrical tape to keep the wires compact. There should not be so much tape that the end is bulbous, but there should be enough to separate and protect all of the wires. All of the exposed wires, including yellow and bare wires cut earlier, should be covered.

Figure 9. Wires in order from left to right: red, brown, orange.

7.1.4 Crimping on Pins

To start the connector side of the temperature probe, strip off about one inch of the gray wire casing. Again, cut off the yellow and bare wires and strip the red, brown, and orange wires. For the next step, use the wire crimpers. Hold the largest part of the pin's tail in place using the 2.3mm crimpers and carefully insert the exposed part of the red wire into the pin. Crimp them together. Finish off by crimping the protrusions from the pin with the 1.6mm crimper. Repeat with the other two wires.

Figure 10. Wires with pin attached.



7.1.5 Assembling Plug

For the next part, insert the pins attached to the wire into the connector that attaches to the controller. Before doing this, all extra parts that go with the same connector should already be attached (the bottom attachment, two washers, and a spacer as shown in Figure 11).

Figure 11. Order of connector pieces.

Look carefully at the bottom of the connector and note that there are four letters present: A, B, C, and D. Only A, B, and D are used. The red pin should be inserted into the 1A slot, brown into the 2B slot, and orange into the 4D slot. Once again, it is important that the order is correct to not cross wires. All three pins are inserted at once, so try to align the pins into a triangle (in

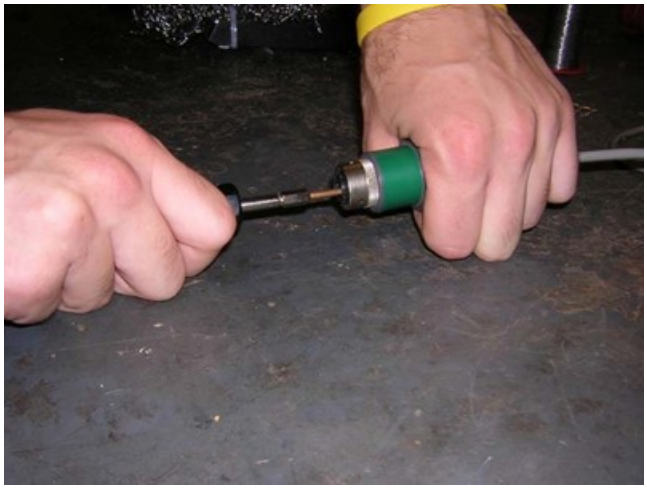
the right order) and then slide them into their correct slots. Use an Allen wrench or other thin object to push the pins all of the way through. A little force may be required to get the pins to the proper depth. The end of the pin should be nearly flush to the end of the connector (see Figure 13). Finish off by pushing all of the parts of the connector together and screwing it together. Finally, screw the clamp onto the base of the connector.

Figure 12. End of the Female Plug.

7.1.6 Repairing Temperature Probes

The procedure for repairing a temperature probe follows the same procedure as creating one from scratch, with the exception that the previously used parts of the wire have to be removed. If there is a noticeably broken or corroded part, remove and replace only that part. The temperature chip is just cut off and thrown away, followed by the procedures listed in section 7.1.2. To remove the pins from the connector, unscrew the bottom and use the pin removal tool to disconnect the pins from the connector. Simply cut off the pins and continue with the gray wire as described in section 7.1.4.

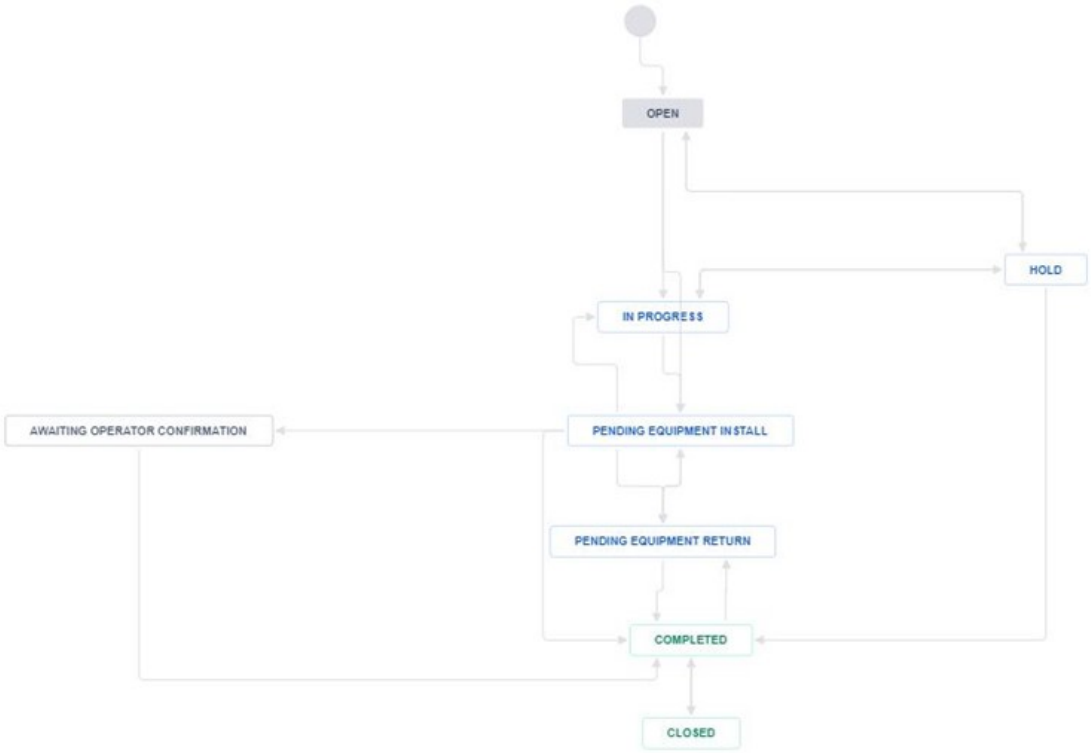
Figure 13. Removing the Connector Pins.



7.1.7 JIRA Workflow

JIRA is the online issue-tracking software used by the Air Quality Research Center at UC Davis. This software has the capability to track different issues from all sites in the sampling network in a user-friendly, highly organized, and searchable way. Each issue has a parent issue based on data received from the field – whether it is an email, phone call, or logsheet comment from the operator – or a review of the memory card data received. Each issue can have many different requests for equipment to fix the issue. These equipment requests are sub-tasks associated with the parent issue. Shown below in Figure 15 is the workflow that an equipment request sub-task can go through as the equipment request is processed.

Figure 14. Equipment request workflow.



TI 226G: Field Safety Plan

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

The purpose of this Field Safety Plan is to describe the procedures, equipment, training, and documentation needed to ensure the safety of field maintenance crews during site maintenance visits.

2. SUMMARY

UC Davis field technicians visit each IMPROVE monitoring site at least once every two years. This document describes the steps to be taken to ensure their safety both at the site and during travel to and from the site. Also addressed is the safety of visitors who might accompany them to the site. Training and documentation required to enhance safety are also described in this Technical Information (TI) Document.

3. CAUTIONS

All UC Davis employees making site visits will be required to read this document and to complete the prescribed training and documentation before embarking on a site visit trip.

4. EQUIPMENT AND SUPPLIES

The following safety-related equipment should be available for the site maintenance crew:

- Ladder or alternative safe roof access

- Safety harness and lanyard to wear while working on the roof
- Other necessary fall protection equipment per fall safety plan
- First aid kit
- SPOT GPS
- Personal protective equipment for power tools (safety glasses, gloves)
- Cell phone
- Closed-toed shoes
- Drinking water
- Insect repellant and mesh hood
- List of nearest emergency room for each site

5. FIELD SAFETY PROCEDURES

5.1 Travel

1) To prevent fatigue field crews should avoid working more than 12 hours on any given day, including on-site time, travel time, and lunchtime. An exception is made for air travel days. The limit for these exceptions is 16 hours and if it must be exceeded, the traveler must attempt to limit the drive between the airport and the hotel to one hour.
2) Drivers should not drive more than two hours before taking a break or switching driving with their trip partner.
3) Texting while driving is not allowed under any circumstances. Not only is it generally unsafe, it is also expressly forbidden by our Federal contract. Drivers will pull over if they need to send or receive a text message.
4) Making or receiving phone calls without a hands-free set while driving is not allowed under any circumstances. Drivers will pull over if they need to use their cell phones.
5) Be sure to rent an off-road vehicle (from National/Enterprise whenever possible, otherwise first obtain prior approval from Risk Management at 530-752-2629) if you need to visit sites requiring off-road access. Drive the off-road vehicle in a safe, responsible manner. Do not travel to off-road sites in a standard passenger vehicle.
6) Do not offer rides to non-UC Davis employees such as friends or hitchhikers. Site operators or other local IMPROVE employees may ride to and from the sites with the UC Davis field crew.

5.2 On-Site Maintenance Work

1) Electrical Safety – no damaged or frayed electrical equipment should be used. Electrical equipment should not be used around water nor during adverse weather conditions such as thunderstorms.
2) Using Tools – apply the safety precautions associated with any tools that are used. Do

not use tools that are broken or that may otherwise be unsafe. Wear appropriate personal protective equipment for each type of tool.

3) Working on the Roof – caution should always be exercised when working on the roof of a shelter. Access the roof only with a ladder or other safe device. Do not climb on unsafe equipment such as chairs or stacked concrete blocks. If there is no safe roof access then do not perform the roof-related tasks such as servicing the stacks.

   Wear a harness if the roof seems to be especially high or steep. Refer to the site-specific fall safety plan if it has been deemed a "high" risk site. Secure the harness to something stable such as a railing or post that has been engineered for either fall arrest or work positioning, depending on the level of risk.

4) Footwear – closed-toed footwear should always be worn when working on-site. Wearing sandals or other open-toed footwear is not allowed.

5) Weather Restrictions – do not work during weather conditions that may be unsafe. During thunderstorms, in particular, stay indoors until conditions become safe.

5.3 Safety for Site Operators and Other Guests

1) Inform all non-UC Davis personnel that safety is a priority during maintenance visits and that they must follow all safety instructions given by the UC Davis staff.

2) The roof restrictions are the same for non-UC Davis personnel as they are for UC Davis staff. Namely, only a ladder or other safe route must access the roof, and a safety harness must be worn if the roof seems especially high or steep.

3) Non-UC Davis personnel are to use tools only at the direction of UC Davis staff. Personal protective equipment must be worn if required for the type of tool.

5.4 General Safety

1) Know the location of the nearest emergency room. When planning the trip obtain this information from the local operator at each site and compile a list including all of the sites on the trip.

2) Carry a first aid kit.

3) Carry a SPOT GPS so you can report your exact location for evacuation or roadside assistance in case of an emergency. Travelers should send a SPOT "We are OK" update when they arrive at the site and a second update when they leave the site.

4) If in a foreign country, know the location and contact information for the nearest U.S. Consulate.

5.5 Environmental Safety

1) Be aware of the effects of heat. Drink plenty of water throughout the day to remain hydrated.

2) Pace yourself when working at high altitude. Stop and take a break if you feel dizzy or short of breath.

3) Be prepared for insects, especially flying insects. Carry insect repellent and a mesh

hood to use when insects are bothersome.

4) Be alert for snakes and spiders. Do not step or place your hands and feet where you cannot see.

5) Be alert for bears or other large animals. Make plenty of noise as you approach any secluded location so the animals will not be surprised by your arrival. Most animals will flee if they can sense that you are coming.

6) There are several urban IMPROVE sites and care should be taken to lock the vehicle and to secure work and personal equipment while at the site.

5.6 Training

1) All UC Davis field staff are required to undertake field maintenance training prior to going on a maintenance trip. *UCD SOP #226: Site Maintenance* and its associated TI documents form the basis for this training. The training is conducted and supervised by experienced members of the UC Davis field staff.

2) First Aid, CPR, and Wilderness training are strongly recommended for field staff. This training is offered on campus through UC Davis Campus Recreation and Unions. Information on classes and schedules can be obtained through the UC Davis Outdoor Adventures website: http://cru.ucdavis.edu/outdooradventures

5.7 Documentation

1) Field staff supervisors should maintain a list of the location of the nearest emergency room to each site. This list should be updated as needed based on information obtained from the site operators during the trip planning stage.

2) Travelers should prepare a trip plan for each trip, to be filed with their supervisor prior to departure. The plan should include:

    a. Where you will be each day (sites visited and planned hotel)

    b. The location of the nearest emergency room each day

    c. Cell phone numbers for each traveler

    d. Emergency contact information for each traveler

    Guidance on preparing a trip plan can be found on the UC Davis Safety Services website:

    http://safetyservices.ucdavis.edu/ps/rm/rmr/fieldOperationalPlanner

    Click on the active link titled “Access the FSTOP System” to log in and receive personal trip planning guidance.

3) Prior to each trip, each traveler should register for UC traveler insurance coverage and should print out the insurance card. Details and registration information can be found on the UC Risk Services website:

    http://www.ucop.edu/risk-services/loss-prevention-control/travel-assistance/index.html

4) Travelers should obtain the rental car contract and keep it in the rental car at all times.

TI 226H: Calibration of Flow Check Devices Using Positive Displacement Flow Meter

TABLE OF CONTENTS

1. PURPOSE AND APPLICABILITY

This technical instruction document describes the procedures for calibrating the flow check devices necessary for performing flow rate measurements on IMPROVE aerosol samplers. The calibration of the flow check device is done by Air Quality Research Center personnel prior to and subsequent to flow rate measurements at an IMPROVE sampling site. Each flow check device is labeled so that its calibration can be tracked through time. All calibrations are stored on the computer network and in the field specialist's flow check device files. The most current calibration equation for each flow check device is written on a sticker, which is pasted on the flow check device gauge following the calibration procedure.

2. RESPONSIBILITIES

2.1 Field Specialist

The field specialist will:

- Train field technicians in the use of flow check device calibration equipment.
- Approve and file the flow check device calibration equation.
- Maintain an accurate database of flow check device calibrations.

2.2 Field Technician

The field technician will:

- Perform the calibration of the flow check device.
- Submit the derived calibration equation to the field specialist for approval.

3. REQUIRED EQUIPMENT AND MATERIALS

The equipment required to calibrate a flow check device includes the following:

a. Definer 220, Mesa Labs, http://drycal.mesalabs.com/definer-series/, accuracy 1%
   - 3/8" I.D. hose, 2'
   - ¼ NPT brass nipple for 3/8" I.D. hose
   - Stack inlet plug for top of IMPROVE $PM_{2.5}$ module tee inlet
   - 3/8" O.D. stainless steel tube, 2"
   - IMPROVE $PM_{2.5}$ module tee plug tapped for ¼ NPT fitting

b. 1 flow check device (orifice meter) and calibration form

c. 1 leak checked IMPROVE $PM_{2.5}$ module

d. 1 IMPROVE controller

e. 1 IMPROVE rocker piston pump with corresponding vacuum line

f. 1 IMPROVE pump relay box

g. 1 leak checked calibration filter cartridge

4. METHODS

This technical note covers the methods for calibrating orifice meters using a Definer 220 as a standard. Section 4.1 covers the theory describing the behavior of orifice meters, while section 4.2 describes the procedures used to calibrate orifice meters against a Definer 220.

4.1 Orifice Meter Theory

An orifice meter consists of a restriction in the air path and a device to measure the pressure drop across the restriction. Orifice meters in the IMPROVE network use magnehelics to measure the pressure drop. The flow check devices consist of a magnehelic, tubing, and a probe that fits into the base of the inlet tee of the $PM_{2.5}$ (fine) sampling modules and at the base of the inlet stack in the PM_{10} (coarse) module. For the five modules, the probe blocks the normal flow through the inlet, forcing all air entering the system to pass through the probe orifice. The flow check device probe is a machined piece with slight variations between the holes drilled and geometry. The results in the need to calibrate each device probe. The digital magnehelics all agree within 1% and no individual calibration is needed for each. The digital magnehelics are, therefore, interchangeable. The probe and magnehelic, hereafter called the flow check device, are calibrated at the Air Quality Research Center (AQRC) at UC Davis (UCD) using a Definer 220.

The flow rate through an orifice meter, Q, depends on the pressure drop across the restriction, δP, and the square root of the density of the air:

$$Q = Q_1 (\delta P)^{\beta} \sqrt{\frac{P_\circ}{P}} \sqrt{\frac{T + 273}{293}} \qquad \text{(TI226-1)}$$

Where P is atmospheric pressure, T is temperature in ℃, and Q_1, β, and P_° are constants. For laminar flow, β =0.5. We express Equation TI226-1 in parameterized form using the magnehelic reading, M, for the pressure drop:

$$Q = 10^{a} M^{b} \sqrt{\frac{P(sea\ level)}{P(site)}} \sqrt{\frac{T + 273}{293}} \qquad \text{(TI226-2)}$$

We have arbitrarily defined all pressures relative to the standard pressure at sea level and all temperatures relative to 20 °C. Thus, the parameters a and b are always calculated relative to 20 °C and UCD. The value of b should be similar to that of β, around 0.5. The advantage in expressing the parameters relative to sea level is that all modules should have parameters with similar values independent of the site elevation.

Because of the difficulties in measuring the ambient pressure at each sample change, we have chosen to use an average pressure based on the elevation of the site. The pressure-elevation function is discussed in SOP201-3.

The reference flow rate is provided by a Definer 220 located in the sampler laboratory at AQRC. Taking the logs of Equation TI226-2, the flow rate equation for the flow check device is

$$\log(Q) = a_\circ + log \sqrt{\left(\frac{29.92}{P}\right)\left(\frac{T + 273}{293}\right)} + b_\circ * \log(M_\circ) \qquad \text{(TI226-3)}$$

The log of the meter reading – Mo – is regressed against the log of the flow rate for a set of four flow rates covering the normal range of the device. The constants relative to the nominal sea level pressure (29.92” Hg) and 20 °C are calculated using

$$a_c = intercept - log \sqrt{\left(\frac{29.92}{P}\right)\left(\frac{T + 273}{293}\right)} \qquad b_\circ = slope \qquad \text{(TI226-4)}$$

4.2 Calibration of an Orifice Meter Using a Definer 220

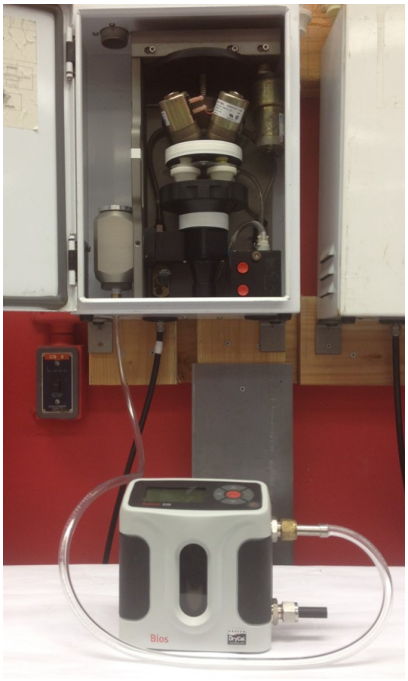
The flow check device, or orifice meter, is used as the standard against which each module in the field is calibrated. The flow check device probe is calibrated against a primary flow device — a Definer 220 — at AQRC both prior to and following calibration at a site. The calibration equation for the flow check device probe is printed on a sticker within the magnehelic side, along with the date of calibration and name of the technician responsible for the equation. A flow

restricting device and a filter cartridge with twelve filters with distinct pressure drops is used to change the flow rate to develop the equation. Finally, a spreadsheet to complete logs and linear regressions is required.

1. Install the calibration cartridge shown in Figure 1 in the module. This cartridge is set up with four cassettes that produce a range of flow rates.
2. Insert Definer 220 probe at bottom of tee and tee plug on top of tee as shown in Figure 2. Ensure that both probe and plug are inserted fully.

Figure 1. Calibration Cartridge.

Figure 2. Calibration system with Definer 220.



3. At the controller press **Menu** from the Home Screen, then **Advanced Menu**, then enter code **9051**.

4. From the Advanced Menu press **Calibration**. Turn on the pump and open solenoid one on module 1A.
5. Turn on the Definer 220 by pressing the red power button in the bottom of the right corner for 2 seconds.
6. When the Definer has been turned on press the red **Enter** button while "Measure" is selected as in Figure 3.
7. Select **Burst** mode and take flow reading for filter position 1 of the calibration cartridge. Ensure that the Definer is set to the standard temperature of 20°C for determining SLPM. This is indicated by "Std. Temp: 20" shown on the definer screen during readings as shown in Figure 4.
8. Record the average flow rate for each filter position in cell **B7** of the calibration spreadsheet shown in Figure 5.

Figure 3. Setting up the Definer 220.

Figure 4. Operating the Definer 220.

Figure 5. Flow check device calibration spreadsheet.

	F-07 PROB												
	Calib. Dat	1/22/2020	Calib. By:	FJ									
	ΔP_{DIGMAG} "H_2O	Q ALICAL lpm	Q_{DIGMAG} lpm	%Diff	LOG DIG_{MAG}	LOG ALICAL	R^2	a	b	23 lpm STP	16.9 lpm STP	Temp °C	BP "Hg
SET1	0.61	23.89	23.89	-0.01%	-0.215	1.378	1.000	1.502	0.575	0.570	0.334	21.9	766.00
	0.58	23.27	23.25	-0.09%	-0.236	1.367							
	0.47	20.61	20.61	-0.01%	-0.327	1.314							
	0.37	18.01	18.02	0.06%	-0.428	1.256							
SET2	0.62	24.12	24.14	0.06%	-0.208	1.382							
	0.59	23.35	23.37	0.06%	-0.232	1.368							
	0.53	22.16	22.13	-0.16%	-0.273	1.346							
	0.36	17.60	17.60	0.00%	-0.446	1.246							
SET3	0.63	24.30	24.34	0.15%	-0.201	1.386							
	0.59	23.50	23.48	-0.09%	-0.228	1.371	Comments:		Average (ABS) of difference between AliCal VS Digital MAG				
	0.49	21.03	21.03	0.01%	-0.312	1.323			0.01%				
	0.39	18.54	18.54	0.01%	-0.407	1.268							

9. Repeat steps 7 and 8 for the remaining filter positions.
10. Remove the Definer plug and tee inlet plug from the module.
11. Insert the flow check device probe into the bottom end of the inlet tee. Ensure that the probe is fully inserted. Attach the magnehelic gauge on a vertical metallic surface as shown in Figure 6. The back end of the gauge base is magnetic.

Figure 6. Calibration system with magnehelic flow meter.

12. Record the magnehelic reading for each filter position on cells B7-B18 of the

calibration spreadsheet.

13. Record the calibration date, technician name, ambient temperature, and pressure on the spreadsheet.
14. The spreadsheet will generate values for R2, intercept, slope, nominal magnehelic value for a flow rate of 23 LPM, and 16.9 LPM at standard temperature and pressure.
15. If the r2 is not better than 0.990, the calibration is invalid. Repeat the orifice meter calibration procedure, beginning with step 2.
16. If the r2 is better than 0.990, write out the equation, the date, technician initials, temperature, and r2 value on a 3 7/16" x 9/16" file folder label and attach it to the side of meter magnehelic.
17. Save the calibration spreadsheet.
18. Share the results of calibration spreadsheet with the field or shop manager for approval.