

**IMPROVE
STANDARD OPERATING PROCEDURES**

**SOP 226
Annual Site Maintenance**

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Technical References

- TI 176A Calibration of Audit Devices Using the Spirometer
- TI 176B Final Flow Rate Audit Calculations
- TI 176C Flow Rate Audits and Adjustment Procedures
- TI 176D IMPROVE Aerosol Sampler Operation Manual

1.0 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) describes the procedures for annual maintenance of equipment in the IMPROVE sampling network. Annual maintenance is solely the responsibility of the field specialist, or field technicians working for the Air Quality Group.

Prior to annual maintenance, the field technician shall review and summarize all the information collected at each site during the previous year in order to characterize the functioning of each site. The data recorded during weekly maintenance of the IMPROVE samplers, as well as any problems detected during quality assurance procedures shall be incorporated into the site summary. This reference will be used to determine whether extra maintenance or troubleshooting is required at each site.

Annual site maintenance shall be performed by Air Quality Group field technicians. Each site will be visited, the cyclones, stacks and inlets cleaned, the electronics checked, the pumps re-built or replaced, and the samplers audited and new calibration equations recorded. Operator training and review sessions, and sampler upgrades shall also be performed at this time.

2.0 RESPONSIBILITIES

2.1 Field Specialist

The field specialist shall:

- oversee and maintain records on site and sampler operation
- schedule standard annual maintenance
- review flow rate audits and calibration equations

2.2 Site Operator

The site operator shall:

- note deviations from normal operation and inform Air Quality Group personnel
- attend site operator training and review sessions during annual maintenance

2.3 Field Technician

The field technician shall:

- Perform annual site maintenance
- Perform site operator training and review sessions
- Maintain records on equipment repair and modification

3.0 REQUIRED EQUIPMENT AND MATERIALS

The equipment and materials required to perform annual site maintenance and flow rate audits are listed below.

- Personal supplies: bug spray, sun screen, first aid supplies, dust mask, protective goggles, gloves, water, flashlight, baby wipes.
- Cleaning supplies: Alcohol, Kimwipes™, cotton tipped applicators, rags, test tube brush for PM₁₀ inlets, hand broom or paint brush for pump house and modules, stack cleaning brush (3" diameter nylon bristle bottle brush with a 9' section of weighted line attached), Scotch-brite™ pads for preparation for painting, silicone lubricant, graphite lubricant
- Audit and calibration supplies: 2 audit devices (calibrated magnehelics with orifice meter probes), vacuum grease, Teflon tape, calculator, calibration cassettes, variable flow restriction device, felt tipped pens; red, blue, green and black, for marking nominal readings, calibration and audit sheets, #8 rubber stopper for leak checking the sampler, forceps
- Stand and external module repairs: lag bolts 1/4x20; 3", 5", nuts, bolts, and washers 1/4x20; 3", 5", 9", wood screws; 3", 5", nails, saw, sand paper, paint for modules, silicone sealant w/dispenser, masking tape (use when painting), PM₁₀ stack gaskets, PM_{2.5} stack gaskets, vent covers
- Pump maintenance supplies: mufflers or brass nipples, orange gaskets, flapper valves, cylinder gasket, aluminum spacer rings, cylinders, brown Teflon piston rings, piston screws, pump capacitors, NPT to vacuum line brass fittings, spare vacuum tubing, vacuum line fittings, large relays for pump house, lock tight, pump house fan (large), delay timers
- Controller module: spare clock controller, fuses (a spare should be taped inside the module), lock-out device, controller fan (small and narrow), override timer, relays (small, plug into base), relay hold down clips, transformers
- Sampling modules: spare cassette hoses, small self-tapping screws for faceplates, elapsed timers, toggle switches, breaker switch, panduit connectors, spare wire; red, orange, yellow, green, blue, black, white, and purple, spare 6 wire cable, solenoids, solenoid o-rings: 2-011, spare tubing: cassette to solenoid, spare magnehelic, spare pressure gauge, valves w/set pins, wire ties, wire tie downs, colored tape, white sticker labels
- Brass fittings and accessory parts: 5/8" vacuum line compression nuts, spare magnehelic nipples, 1/4 NPT to vacuum line brass elbows, CAJON™ VCO female connector, CAJON™ VCO male connector, 1/4 NPT pipe extender fitting.

- Cyclone parts:
cyclone port covers
o-rings

o-rings	old style	new style
lower funnel to catch cup	2-118	same
cyclone/T junction to lower funnel	2-130	2-128
cyclone/T junction	2-123	same
cyclone/T junction to upper funnel	2-124	same
cyclone throat insert	2-014	same
upper funnel screw o-rings	2-008	none
magnehelic port nipples	2-008	same
cover plate to upper funnel	2-156	same
cover plate inserts: upper o-ring	2-016	same
cover plate inserts: lower o-ring	2-017	2-016
cyclone T to stack bottom plug	2-216	same
cyclone T to stack	2-222	
solenoid o-ring	2-011	same
denuder screw o-ring	2-008	same
PM ₁₀ funnel o-rings	2-124	same
PM ₁₀ inlet o-rings: Sierra	2-023	same
PM ₁₀ inlet o-rings: Wedding	2-023	same
PM _{2.5} inlet o-rings	2-129	same

magnehelic port nipples, magnehelic tubing, knurled knob on a 10-24x3" screw for cyclone cover plate, hold down clamps for filters, new cyclone T junctions with 10-24x1" screws, new cyclone cover plate inserts for old cover plates, right angle drill adapter, template for installing new T's for cyclones

- Inlet and stack parts: spare PM_{2.5} inlets, PM₁₀ Wedding inlet cover plate screws, PM₁₀ Sierra inlet water collection cups, stack bracket/holder, stack bottom plugs, stack bottom plug plugs, denuders, sheet metal screws for holding in denuders
- Tubing: spare vacuum tubing to replace any damaged or stressed tubing, Tygon® tubing (3/16" I.D., 1/16" wall) to replace weakened or damaged magnehelic hoses.
- Tool kit with 8" and 10" adjustable crescent wrench, channel lock pliers, needle nose pliers, cutting pliers, standard 1/4" through 11/16" combination wrench set, ignition wrench set (including an 11/64" wrench), Phillips and Standard screwdrivers, wire snips, wire crimping and stripping tool, utility knife, line powered drill, standard drill bit set, multimeter (AC/DC volt/ohm meter), wire ties, electrical tape, colored paper or vinyl tape (red, yellow, green, blue, black and white), and Teflon plumbers tape.

4.0 METHODS

Annual maintenance is performed by field technicians, generally in the spring or summer. This annual visit to the site is an opportunity to repair non-vital sampler components, 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 annual maintenance procedures.

4.1 Preparation for annual maintenance loop

4.2 Annual site maintenance

4.3 Operator training and review

4.1 Preparation for Annual Maintenance Loop

Preparation for annual site maintenance involves contacting each site, scheduling visit dates and times, and creating a site audit and maintenance kit. The Field Specialist is responsible for scheduling maintenance trips and overseeing the training and supplying of the field technicians both prior to leaving the Air Quality Group and while in the field. The process to prepare for annual maintenance loops is described in the following section.

1. The Field Specialist notifies the appropriate land management departments of the scheduled site visit at least one month prior to the visit date. The information transmitted includes which site or sites will be visited, the approximate date of the visit(s), and the name of the visiting field technician.
2. The field technician assembles a maintenance loop notebook containing the following information for each site:
 - Flow histories for all modules
 - Results of the A vs. B module plot (PIXE Sulfur vs. SO_4^{-2} from Ion Chromatography) to determine whether there are discrepancies between the modules in air volume sampled.
 - Photocopy of the audit form from which the current site calibration equations were derived.
 - Photocopy of the site maintenance report and comments from the previous year
 - Blank audit and calibration forms
 - Blank maintenance report and site configuration checklist forms from V:\Field\Maint
 - Pump strength history
 - Notes and comments from the past year's log sheets regarding sampler problems.
3. The field technician notifies the site operator of the impending visit at least two weeks prior to scheduled date. The site operator should have received notification from the appropriate land management department of the scheduled visit prior to this time. The following topics are covered during operator notification.
 - The exact date of scheduled maintenance at the site
 - Scheduling of operator training sessions

- Details of site access, including keys, combinations, road conditions, etc.
 - Past performance of the sampler
 - Current problems the with the sampler, power, site, etc.
4. The field technician constructs, loads, and leak checks two cassettes for each filter sampling configuration. These cassettes, called annual maintenance audit cassettes, shall be used to set the nominal flow rate and perform audits in each module. The flow rates through both cassettes must agree, and must be consistent with the observed flow rates through the normal sampling cassettes installed at the site. IMPROVE network cassette configurations include:
 - Module A cassette loaded with a Teflo™ filter and mask size M1 (area 2.2 cm²).
 - Module A cassette loaded with a Teflo™ filter and no mask.
 - Module A/S cassette loaded with a Teflo™ filter and mask size M1 (area 2.2 cm²) in stage 1, and a Na₂CO₃ impregnated quartz filter in stage 2.
 - Module B cassette loaded with a Nylasorb filter.
 - Module C cassette loaded with a Pallflex™ quartz filter.
 - Module C/C cassette loaded with one Pallflex™ quartz filter in stage 1 and one in stage 2.
 - Module D cassette loaded with a Teflo™ filter and no mask.
 - Module D/S cassette loaded with a Teflo™ filter and no mask in stage 1, and a Na₂CO₃ impregnated quartz filter in stage 2.
 5. The field technician checks the calibration of two audit devices (orifice meters) with the spirometer following the procedures of TI 176A. If the flow rates are not within 2% of the previous calibration, the audit device is re-calibrated.
 6. The field technician creates annual site flow rate audit sheets for each site being visited using the Autocal database, or manually as described in TI 176B.
 7. 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 notebook should be reviewed to determine any extra work or suspected problems for which the technician must be prepared.
 8. The field technician prepares clean, coated denuders to replace the used denuders in the B modules at each site. To clean and coat each denuder, the technician shall:
 - a. Place the denuder in a 1 liter graduated cylinder in an ultrasound bath. Fill the cylinder with 1 liter of de-ionized water, 10ml of reagent grade ammonia and 1/16 teaspoon of Alconox™ glass cleaner.
 - b. Run the ultrasound bath for at least 30 minutes.
 - c. Remove the denuder promptly and rinse thoroughly with hot water for several minutes.
 - d. Rinse the denuder with distilled de-ionized water.
 - e. Allow the denuder to dry, rinsing it with reagent grade alcohol to remove all water.
 - f. Immerse the denuder completely in the Na₂CO₃ solution for several minutes, agitating it to ensure all surfaces are coated
 - Stock solution should be in a labeled, sealed bottle on the supplies shelf in the shop.

- If none is available, create a solution of Na₂CO₃ and reagent grade glycerol in distilled water. The required concentrations are 71grams of Na₂CO₃ and 30ml of glycerol per liter of water. Agitate the solution thoroughly until all the Na₂CO₃ is dissolved. Heating the distilled water aids dissolving the Na₂CO₃. Store the Na₂CO₃ solution in a clean, sealed, labeled beaker.
- g. Remove the denuder from the solution and allow it to air dry. Place it on clean lab towels over plastic to absorb excess Na₂CO₃ and protect the lab floor.
- h. Store the denuder in a clean plastic bag labeled "Cleaned and Coated Denuders".

4.2 Annual Site Maintenance

Once the field technician has arrived at the site, the following procedures are performed.

- 4.2.1 Pre-maintenance Inspection at the Site
- 4.2.2 Flow Rate Audit
- 4.2.3 Sampler Cleaning and Maintenance
- 4.2.4 Sampler Calibration
- 4.2.5 Post-calibration check

4.2.1 Pre-Maintenance Inspection at Site

The pre-maintenance inspection involves filling out Figure 1 and Figure 2, forms for describing the status of the site. Any repairs or changes to the sampler or site should be noted on these forms. These tables shall be filed with the annual maintenance reports for each site as a record of actions taken at the site. 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.
3. Note the condition of the sampler modules; do they require painting?
4. For an outdoors site, check the integrity of the pump house, verifying that both the switched and the constant power outlets are functional.
5. Locate the current week's log sheet. If the field technician is unable to obtain the blue box and log sheet, he shall record information pertinent to the samples in the field notebook and on a sheet of paper to be left in the controller module for the site operator.
6. If the sampler is currently running (Wednesday or Saturday site visit), turn it off using the clock controller manual override buttons. Note the shutoff time on the log sheet. Try to limit sampler "down time" to less than four hours, as samples with elapsed times less than 18 hours are flagged as invalid and not analyzed.
7. Visually inspect the sample cassettes and elapsed timers. Note and correct any errors involving sample change protocol.
8. Record gauge readings for each cassette in each module. Note the final readings on the log sheet for any cassettes that contain exposed filters.

4.2.2 Flow Rate Audit

Remove the cassettes, replace their red caps, and place them in their blue box or another clean area.

1. Install the annual maintenance audit cassettes in each module.



"TI 176D.doc"

2. Following the procedures in TI 176C, perform an initial flow rate audit.
3. If necessary, perform a four point audit.

Figure 1 Site Maintenance Report

SITE _____ DATE _____ NAME _____

	PROBLEMS	OK ?	PARTS REPLACED
Control Module			
Module A			
B			
C			
D			
Pumps			
Stand or Shelter			

COMMENTS:

Figure 2 Site Configuration Check List

Site name: _____ Date: _____ Initials: _____

Circle one: **Outdoor ARS Shed IMPROVE Shed Existing Building**

Is the D module orifice meter between the solenoid manifold and the VOC fitting? **Yes No**

Is the sampler enclosure climate controlled? **Yes No** Modules present: **A A/S B C C/C D D/S**

See descriptions to determine: Controller module type _____ D module orifice meter type _____

Put an X next to all equipment present:

- ___ pump house w/relays ___ thermometer ___ phone near sampler? # _____
- ___ pump enclosure w/o relays ___ electrical outlet ___ ozone monitor or nephelometer
- ___ plastic critical flow device ___ critical orifice ___ brass critical flow device

Indicate the filter channel for each solenoid

Module	manifold position: left	manifold position: left center	manifold position: right center	manifold position: right
A				
B				
C				
D				

Indicate the filter channel for each elapsed timer

Module	upper left timer	upper right timer	lower left timer	lower right timer
A				
B				
C				
D				

Fill in the information corresponding to each sampling module

Module	old or new style cyclone?	Old or new style cover plate?	pump rebuild date	date cylinders replaced	Stack length? (in feet)	Anodized stacks?	inlet type (new, old,)?	inlets anodized?
A								
B								
C								
D							X	X

Where is the thermometer located?

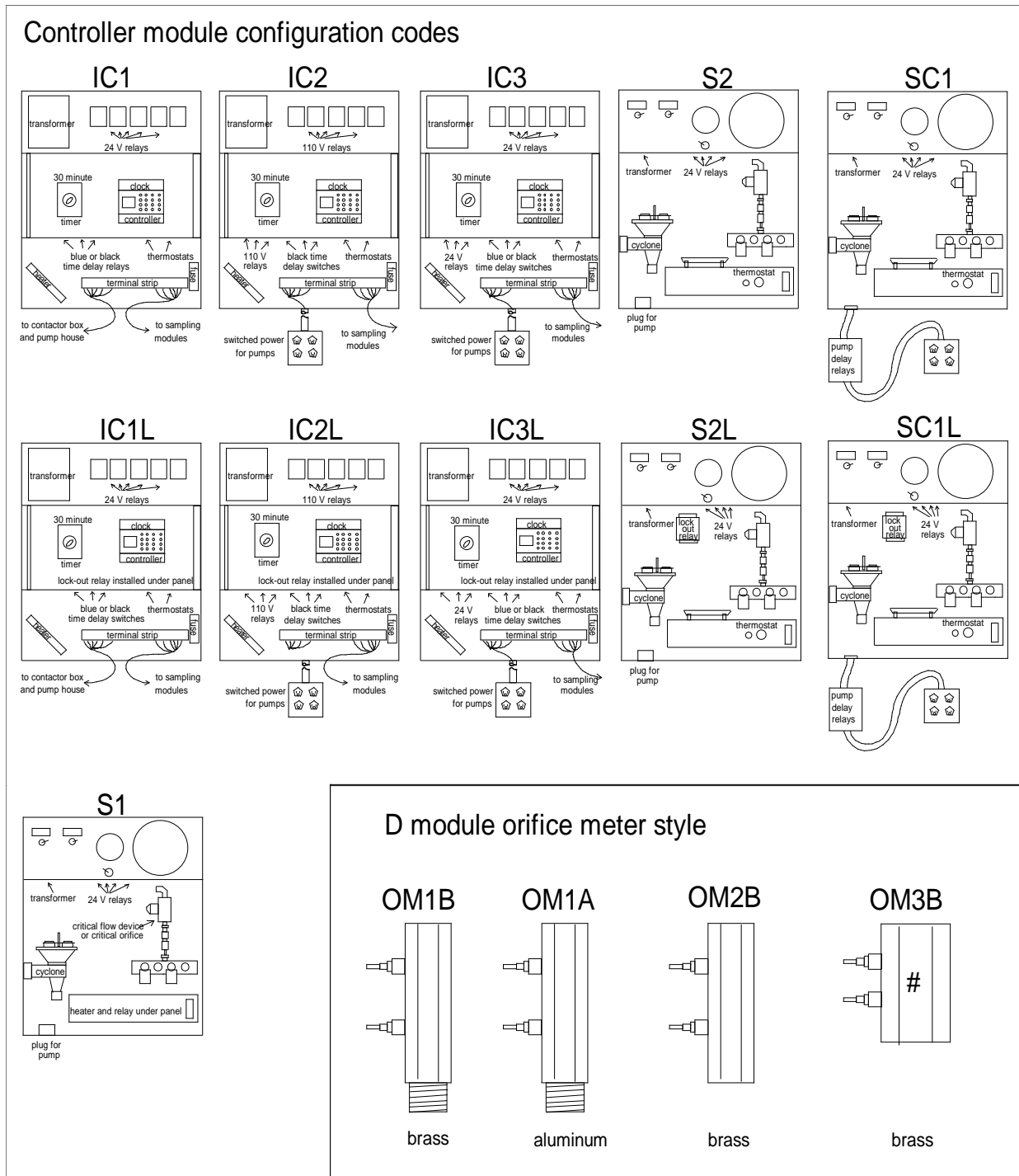
Describe the power supply at the site (e.g. is there an exclusive breaker for the sampler? where is the breaker? What size is the breaker? Where is the outside power connected; at the pump house? at the controller module?).

Does the site have a **Sierra** or a **Wedding** PM₁₀ inlet? If Sierra, does it have a **plastic, metal, or glass** jar?

Where are the pumps located and what type of cylinders do they have?

Describe any site access restrictions (How to unlock module, site or gate locks? Escort required? Transportation to the site by the operator required? Day or time of day restrictions for visits?)

Figure 3 Controller Module and Orifice Meter Configurations



Notes:

4.2.3 Sampler Cleaning and Maintenance

4.2.3.1 Clean Cyclones, Cover Plates, and Stack Tee's.

1. Use a short flat head screwdriver to remove the screws mounting the cyclones to the stack tee's, and disconnect the magnehelic hoses
2. Move the cyclones to an area where you can work comfortably, and without dropping any tools or parts into dirt, water, etc.
3. As each cyclone is disassembled and reassembled, check each O-ring. If any O-ring is damaged or missing, replace it and note it on the checklist. 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 Kimwipes™, or another sterile, dust free cloth. Do not get alcohol on the o-rings as this will speed their degradation.
4. Remove the catch cup, clean and set aside.
5. Remove and clean the lower funnel. In old style cyclones the lower funnel is bolted to the cyclone body. In new style cyclones, the funnel is held in place by an o-ring. In either case, the two to four screws running through the cyclone body should be removed.
6. Remove the manifold plate from the upper cyclone funnel by tightening the cassette hold-down plate onto the port covers, then pulling up on the cassette hold-down plate until the manifold plate pops off the funnel. If it is too firmly seated for this, insert a long screwdriver between the manifold plate and the cassette hold-down plate and use this as a lever to help pop the manifold off the funnel.
7. Clean the manifold plate, checking to be sure the knurl-nut and threaded stock are not bent or damaged.
8. Carefully inspect the cassette mounting ports; verify that no o-rings are missing and the ports are firmly installed in the manifold plate. If any ports are loose, remove the cover plate and replace it with a spare cover plate from the parts kit. The cover plate with the loose ports should be repaired as soon as possible to allow the silicone sealant at least three days to cure (cease out-gassing) prior to reuse. To repair the cover plate, remove the loose ports, apply a small amount of silicone sealant on the lower o-ring of the port, and re-install the port in the manifold plate. Place the cover plate in the spare parts kit, labeling it with the date the cover plate was repaired to ensure that it is not reused until the silicone sealant has cured.
9. Clean the port caps, if necessary, and check to be sure they fit securely on the cassette mounting ports.
10. The upper funnel on old style cyclones contain four screws holding the funnel to the cyclone body; a feature missing on the new style cyclones. Remove these screws, checking and replacing their o-rings if necessary. Twist the cyclone body to separate it from the upper funnel.
11. Remove the cyclone throat from the base of the upper funnel, checking the o-ring holding it in position. Clean the funnel and the throat and re-assemble them.
12. Clean the cyclone body, being sure to check the stack tee o-ring.
13. Reassemble the cyclone unit.

14. Remove and clean the D module manifold plate, using the procedures described above in steps 6 through 9.

4.2.3.2 Clean the Stacks, Inlets, Tees, and Stack Bottom Plugs.

1. Remove the stack bottom plug, checking the o-ring and replacing it if necessary. Clean the tees with alcohol on a clean rag.
2. Remove and clean the inlet caps from the top of the stacks. Check and replace the o-rings if necessary. Use a test tube brush to clean the screen and remove dust of spider webs.
 - If the D module inlet is a Wedding 18.9 lpm inlet(mushroom shape) clean it as follows:
 - i. Wipe the inside of the stack fitting sleeve with a clean, lint free cloth.
 - ii. Unscrew the four flat head screws on the top of the inlet, remove the top plate, and gently brush the inside with a test tube brush. Take care to avoid disrupting the arrangement of the air flow vanes.
 - iii. Dump out any water inside the inlet (there shouldn't be any).
 - iv. Replace the top plate, securing it firmly in place. Do not strip the screws. If the screws appear stripped, replace them.
 - v. 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 the corner of a razor blade.
 - vi. Coat the o-rings with a small amount of vacuum grease.
 - If the D module inlet is a Sierra Anderson 246B (Olympic torch shape) clean it as follows:
 - i. Unscrew the water trap bottle, either plastic or glass, from the metal cover.
 - ii. Empty the bottle and wipe out any sediments or material 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.
 - iii. Reinstall the water trap bottle.
 - iv. Unscrew the four Phillips head screws on the top of the inlet and remove the top plate. Clean the cone attached to the top plate and the inlet funnel with a lint free cloth, such as a Kimwipe™, and alcohol.
 - v. Clean the exit tube for the inlet funnel with a cotton tipped applicator and alcohol
 - vi. Reassemble the inlet and reinstall the four screws on the top of the inlet. If the screws appear to be stripped, replace them. They are 8-32 x 1/2" Phillips head screws.
 - vii. 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 7 1/2" above the base of the inlet.
 - viii. Clean the impaction surface thoroughly with lint free cloths and alcohol. Note that it will be coated with vacuum grease and may be sticky.
 - ix. Clean all interior surfaces with lint free cloths or cotton tipped applicators and alcohol.

- x. Use a cotton tipped applicator to evenly apply a small amount of vacuum grease to the impaction surface inside the inlet.
 - xi. Reassemble the inlet head.
 - xii. 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 the corner of a razor blade.
 - xiii. Coat the o-rings with a small amount of vacuum grease.
3. Remove the denuder from the B module by unscrewing the o-ring fit set screw in the side of the stack, allowing the denuder to drop out. Replace the o-ring on the set screw if necessary. Use a felt tipped pen to label the denuder as used.
 4. Clean the inlet stacks using a stack brush, or a clean rag coated with alcohol, with a 10' length of weighted string attached. Drop the weight down the stack, and use the string to pull the brush through. Clean each stack at least twice.
 5. Use alcohol and a clean rag or Kimwipes™ to clean the inlet tee. Inspect and replace any damaged o-rings.
 6. Replace the used denuder with a clean, coated denuder. Use a screwdriver to hold the denuder up in the stack above the set screw, thread the set screw in until an o-ring seal is reached, then lower the denuder into position. If you touched the denuder, clean your hands.
 7. Reinstall the inlet caps and stack bottom plugs.

4.2.3.3 Clean the Interior of the Modules and Check All Hoses, Wires, and Connectors.

1. Replace missing labels, etc. on the faceplate and solenoids.
2. Brush out the bottom of the module to eliminate fugitive dust. Be sure the vents are all clear of debris.
3. If any parts, such as the faceplate, relays, etc. are loose, secure them.
4. Check for split hose ends on the brass nipples off the cyclone and the back of the magnehelic gauge. Clip the damaged ends or, if the tubing is showing signs of wear, replace it with new tubing.
5. Tighten or replace loose compression fittings.
6. Tighten or replace loose panduits.
7. Check for loose wires bundles. Use wire ties and anchors to keep wires out of the way of the site operator

4.2.3.4 Check the Solenoids, Elapsed Timers, Vacuum Gauge, and Magnehelic.

1. If one of the solenoids is making excessive noise, it should be replaced, especially if the site is in an area frequented by people.
 - a. Unscrew the two screws and nuts holding the solenoid in place.
 - b. Pull the solenoid straight out; it is held in place by an o-ring.
 - c. Disconnect the wires from the solenoid at the terminal strip.
 - d. Install a new solenoid, pushing it firmly into place
 - e. Connect the wires from the new solenoid to the proper terminal strip positions.
 - f. Test the new solenoid to determine whether it is quieter. If it is not quieter, remove it, label it as “noisy” , and replace it.

- g. Bolt the new solenoid in place.
2. If any elapsed timer is difficult to reset, i.e. the reset button must be pushed several times to return it to a reading of 00.00, it must be cleaned.
 - a. Using the edge of a razor blade, pry out the clear plastic cover plate.
 - b. Push the gray wires coming out of the back of the elapsed timer into the timer body while simultaneously pulling out on the reset button. The workings of the timer should slide out.
 - c. Use a silicone lubricant to spray the gears and reset mechanism, repeatedly pressing the reset button while doing so.
 - d. Once the timer is resetting smoothly and easily, carefully replace it in the timer body, pulling gently on the gray wires to pull the timer workings into position.
 - e. Snap the clear plastic cover back in place.
 - f. If the timer appears irreparable, disconnect the gray wires from the timer at the terminal strip. Next, unscrew the knurled knob on the back of the timer that holds the bracket securing the timer to the faceplate. Pull the timer out through the front of the faceplate. Replace it with a new timer.
3. If the vacuum gauge appears to be sticking, for example if the reading changes when the gauge is tapped, it must be cleaned.
 - a. Unscrew the clear plastic cover plate.
 - b. Remove the needle with needle nose pliers.
 - c. Remove the faceplate by unscrewing the two screws holding it in place.
 - d. Spray the mechanism with silicone lubricant
 - e. Re-assemble the gauge, installing the needle so that it indicates 0"Hg when there is no vacuum.
 - f. Screw the clear plastic cover plate back on.
 - g. If the gauge continues to stick, replace the gauge by disconnecting it from the vacuum line to the manifold, unscrewing the two nuts on the back holding it to the faceplate, and pulling it out through the front of the faceplate. When installing the new gauge, be certain to securely tighten the vacuum line to the new gauge.
4. If the magnehelic appears to be damaged or is not functioning, replace it with a new magnehelic. Verify that the hoses to the magnehelic are not damaged or clogged as these may cause anomalous readings.

4.2.3.5 Pump Maintenance

1. Listen to each pump to determine whether it is making unusual noises. Check the pump status plots and determine which pump displayed the largest change in open end vacuum since the last annual maintenance visit. Disconnect this pump from the vacuum line to the sampler module.
2. Use a socket wrench to remove the three bolts on each head. Remove the piston cover plate slowly, as the orange head gasket may be stuck to the head and could tear.
3. Check the head gasket for deterioration such as cracks or tears. If damage other than wear around the screw holes is noted, replace the gasket.

4. Check for deterioration of the valve plate assembly. The valves should lie flat on the plate. If not, they will not function efficiently. To remove and replace the valves:
 - a. Lift the valve plate assembly off the pump, noting the orientation of the flapper valves.
 - b. Using a flat head screwdriver and a 5/16" ignition wrench, unscrew the nut holding the flapper valves in place.
 - c. Remove the flapper valves, the square valve mounting plates, and the screw and bolt. Save the two square valve mounting plate, the screw and the bolt. The flapper valves, single pieces of spring steel, may be discarded if deformed. If not deformed, they may be cleaned for reuse with alcohol and a clean cloth.
 - d. Clean the valve plate assembly using a lint free cloth and alcohol. Be sure to remove the deposits that were underneath the flapper valves.
 - e. Install cleaned or new flapper valves on the valve plate. Place the square mounting plate on the screw, followed by the flapper valve. Install the screw on the valve assembly. Install a flapper valve, the mounting plate, and the nut on the end of the screw where it protrudes through the plate.
 - f. Before tightening the screw, adjust the positioning of the flapper valves and mounting plates. The flapper valves must lie flush on the surface of the valve plate, and be oriented to cover the holes in the plate. The valve mounting plates should be squarely set on the flapper valves, angled settings will place undue stress on the valve causing it to fail.
 - g. Tighten the screw and nut, then check the orientation of the flapper valves and mounting plates.
 - If the flapper valves are not flush with the valve plate, remove the screw and valves, check for and remove any deposits, then flip the valves over and reinstall.
 - If the flapper valves are not centered over the valve holes, loosen the screw and readjust the valves.
 - If the mounting plates are not aligned with the flapper valves, loosen the screw and readjust the mounting plates.
 - h. Inspect the cylinder o-ring. If it is damaged, replace it.
 - i. Inspect the cylinder in which each piston moves. Look for signs of wear such as deep or extensive scratches in the anodized coating on the inside of the cylinder. If significant damage is seen, the cylinder must be replaced.
 - j. Inspect the retainer plate and the valve plate to determine whether there is adequate clearance between the piston and the valve plate. If there are scores or dents on either fitting, and the pump makes knocking or clanking noises while running, the clearance is inadequate and shims must be installed. Carefully, lift the affected cylinder slightly off the body of the pump, and slip a metal shim underneath the cylinder. Lower the cylinder back into position, noting that it has an inner lip that fits within the pump body.
 - k. Inspect the piston cup, the beige plastic gasket mounted on each piston. Replace cups which appear thin compared to new ones. These cups last about two and a half years, so are generally changed every even numbered year.

However, they are always inspected and, if badly worn, are replaced. To replace the cups,

- i. Using a Phillips screwdriver, unscrew the two screws on the retainer plate of a piston. Use caution to avoid stripping the screws.
 - If one screw has been removed, but the other is stripped, angle the tip of a large flat head screwdriver against the top edge of the hole from the removed screw. Hit the screwdriver with a hammer to shift the position of the retainer plate, then move the plate back. This should loosen the stripped screw enough to allow removal. Be careful to avoid damaging the threads in the hole.
 - If both screws are stuck and stripped, they must be drilled out. This is preferably done in a shop, so the pump should be mailed back to the Air Quality Group. Replace the pump with one of the spare pumps taken along during maintenance. If necessary, call the Air Quality Group and request a replacement pump.
- ii. Remove the retainer plate and the beige plastic cup.
- iii. Holding the cylinders in place, push the other piston to its lowest position, thereby moving the piston being worked on into its highest position.
- iv. Install a new cup and screw the retaining plate down firmly to hold the cup in place. Be sure the cup is centered under the retaining plate.
- v. Repeat steps i. through iv. for the other piston.
- l. If it is not the scheduled replacement year for the cups, but the cups on one pump are severely worn, the technician shall check, and replace if necessary, the cups on the pump with the next highest vacuum change. Until a pump not requiring new cups is found, the inspection and replacement process will continue.
- m. Reassemble the pump.
 - i. Verify that both cylinders are seated properly within the pump body.
 - ii. Verify that the cylinder o-ring is in place and undamaged.
 - iii. Install the head gaskets on the pump heads.
 - iv. Install the valve plate assembly on the head gasket, aligning the plate such that the flapper valve is positioned in the quarter circular opening in the gasket. With the valve plate assembly in this orientation, the small hole on the edge of the plate should be aligned with the protrusion on the head beneath the intake port. If it is not aligned, check the orientation of the flapper valve on the plate, and the positioning of the plate.
 - v. Flip the assembly created in step iv. over onto the remainder of the pump, noting that the air inlet side of the pump is opposite the electrical box and capacitor.
 - vi. Verify that the alignment is correct, and tighten everything down with the six bolts.
 - vii. Write the date that the pump was maintained on the top of the pump, removing the previous maintenance date.
- n. Test the pump. Plug it in.

- It should start promptly, if not, and there is something blocking the air inlet, verify that the pump is turned on and has power. If it still will not start, take it apart again as something may be jammed.
 - The pump should not make loud knocking noises. If it makes knocking or grinding noises, turn it off. Something was not assembled correctly, or it needs another shim.
 - Attach a vacuum gauge to the pump. If the vacuum reading on the gauge has not improved, take the pump apart again, inspect it, and reassemble it. If the pump vacuum still reads more than 2" Hg lower than the other pumps at the site, label it as needing maintenance, and replace the pump with a spare.
- o. Once the pump is repaired, reconnect it to the vacuum line to the sampler module and plug it into its switched outlet.

4.2.3.6 Inspect the Sampler Stand or Structure and the Sampling Modules.

Look for deterioration of the stand or structure, noting it in the maintenance loop note book. The modules should be securely attached to the mounting structure, and the stacks should not move when the wind blows.

1. Repair loose joints with wood screws or lag bolts. Replace any structurally unsound boards or beams.
2. Verify that all the modules are mounted securely, and that the stacks are stable, especially the D module stack. The D module stack, if it extends farther than 3' from any support may require guy lines to prevent excessive motion in the wind. However, before installing guy lines in pre-existing buildings, obtain permission from the site manager. Also, for any building, if the guy line anchors must be drilled into the building, be sure to seal the area well with roof caulking to prevent water damage.
 - a. The simplest guy line method for D modules having Sierra Anderson inlet heads (Olympic torch shape) involves three guy lines running from points on the roof or stand to the inlet head. The four posts on the Sierra Anderson inlet are points for guy line connections.
 - b. D modules having Wedding inlets (mushroom shape) are more difficult to guy as the inlet provides no connection points. Bolt a pipe bracket around the stack just below the inlet head and connect the guy lines to this bracket. As with the Sierra Anderson inlet, three guy lines are generally effective in reducing wind motion.
3. If the sampler is mounted inside a pre-existing building which is experiencing structural problems, bring this to the attention of the manager of the building before attempting repairs.
4. Note the condition of the exterior of the modules. If fiberglass is coming off the module, it must be repainted for protection. Repainting should be done as the last step of annual maintenance, but only if no sampling will occur at the site for at least twenty-four hours following the painting of the modules. Before painting the modules, complete all other facets of annual maintenance,

including operator training and flow rate audits. Once annual maintenance has been completed, perform the following:

- a. Gently sand the modules to be painted to remove loose fiberglass fibers.
- b. Prepare water based acrylic enamel paint in clear or slate gray for painting the module.
- c. Cover all metal fittings, vents, and any equipment that may be sensitive to the paint.
- d. If there is an ozone monitor at the site, do not use paint in aerosol cans, instead, brush the paint on the modules.
- e. Paint the modules after all other site maintenance, flow rate audits, and operator training procedures are completed.
- f. Do not paint the modules unless 24 hours of drying time prior to the next sampling period are available.

4.2.3.7 Inspect and Clean the Pump House or Pump Area.

For an outdoor site,

1. Check the stability of the pump house, repair or add bracing as necessary.
2. Brush out the pump house, removing all dirt, spider webs, insect populations, etc.
3. Verify that the four hot power outlets in the pump house are all functional with a voltmeter. If they are not functional, turn off the power at the breaker, then repair the wiring.
4. For sites that are indoors and climate controlled, step 4 can be skipped. For outdoors or indoors sites without climate control, verify that the cooling fan is functioning; it should run if the temperature inside the pump house is higher than 70°.
 - a. If the temperature is over 90° and the fan is not functional, use a jumper wire to bypass the thermostat for the fan.
 - If the fan starts, the thermostat must be replaced.
 - If the fan doesn't start, check the power using a voltmeter. If there is power, the fan is damaged and must be replaced.
 - b. If the temperature is under 90° and the fan is not running, test the fan by using a jumper wire to bypass the thermostat for the fan.
 - If the fan starts, it is functioning properly.
 - If the fan doesn't start, check the power using a voltmeter. If there is power, the fan is damaged and must be replaced.
 - c. If the temperature is under 60° and the fan is running, the thermostat is damaged and must be replaced.
5. Verify that the switched outlets for the pump are functioning properly. When the 30 minute timer in a control module or the pump override switch in a controller module A are turned on, the pumps should turn on in sequence at 8 second intervals. The sequence is Module A pump, followed by B, then C, then D. If two pumps come on at the same time, one of the timers is bad and must be replaced.

For an indoor site,

1. Brush out the pump area, removing all dirt, spider webs, insect populations, etc.

2. Verify that the switched outlets for the pump are functioning properly. When the 30 minute timer in a control module or the pump override switch in a controller module A are turned on, the pumps should turn on in sequence at 8 second intervals. The sequence is Module A pump, followed by B, then C, then D. If two pumps come on at the same time, one of the delay relays in the controller module or, at sites having controller module A's, in the relay box, is bad and must be replaced.
3. Verify that the pumps are in an area having enough air flow for effective cooling. If not, move or rearrange the pumps.

4.2.3.8 Inspect the Controller Module.

For both controller modules and controller module A samplers, perform the following:

1. Check the functioning of the cooling fan; it should run if the temperature inside the module is higher than 70°.
 - a. If the temperature in the module is between 70° and 90°, and the fan is not functional, use a jumper wire to bypass the thermostat for the fan.
 - If the fan starts, for an A module controller, the thermostat must be replaced.
 - If the fan starts for a controller module, the thermostat must be adjusted. To adjust the thermostat in a controller module remove the plastic cover on the thermostat and adjust the screw until the fan starts.
 - If the fan doesn't start, check the power using a voltmeter. If there is power, the fan is damaged and must be replaced.
 - b. If the temperature in the module is below 60° and the fan is running,
 - For an A module controller, the thermostat must be replaced.
 - For a controller module, the thermostat must be adjusted. To adjust the thermostat in a controller module remove the plastic cover on the thermostat and adjust the screw until the fan turns off.
2. Verify that the heater is functional. The heater should run if the temperature approaches freezing. Use a jumper wire to bypass the thermostat for the heater to test whether it is functional.
 - a. If the temperature in the module is below 40° and the heater is not running,
 - For an A module controller, the thermostat must be replaced.
 - For a controller module, the thermostat must be adjusted. To adjust the thermostat in a controller module remove the plastic cover on the thermostat and adjust the screw until the heater starts.
 - If the heater doesn't start, check the power using a voltmeter. If there is power, the heater is damaged and must be replaced.
 - b. If the temperature in the module is above 40° and the heater is running,
 - For an A module controller, the thermostat must be replaced.
 - For a controller module, the thermostat must be adjusted. To adjust the thermostat in a controller module remove the plastic cover on the thermostat and adjust the screw until the heater turns off.

3. Check the clock controller display, including the current time and day and the sampling programs. Reference TI 176D or SOP 176 section 4.3 for clock controller programs.
4. For controller modules, not module A controllers, remove the fuse in the lower right corner, and leave the clock controller without power for at least 30 minutes to test the clock's internal batteries. If the clock loses the correct time, or malfunctions while without power, replace it and return the bad clock to be fixed. Replace the fuse when the test is completed. Verify that there is a spare fuse for the module taped to the wall.
5. For module A controllers, turn off the breaker switch on the heater manifold, to leave the clock controller without power for 30 minutes as a test of the clock's internal batteries. If the clock loses the correct time, or malfunctions while without power, replace it with a new clock and return the bad clock to be repaired. Turn the breaker switch back on when the test is completed.

4.2.3.9 Reinstall the Cyclone Assemblies in the Sampling Modules.

1. Carefully re-seat the cyclones in the stack inlet tee. Note that this is an o-ring fit and should not be loose.
2. Replace the two ¼-20 x ½” mounting screws, bolting them through the bottom of the tee bracket into the cyclone body.
3. Reattach the magnehelic hoses, verifying that the low pressure hose runs to the nipple on the cyclone upper funnel and the high pressure hose runs to the nipple on the back of the cyclone body. Recall also that the center port on the back of the magnehelic is the low pressure port while the port on the top is the high pressure port.
4. Install the audit filters on the cyclones.

4.2.3.10 Leak Check the Sampling Modules.

1. To leak check modules A, B, and C,
 - a. Verify that the stack bottom plug is installed.
 - b. Remove the inlet from the stack and install a rubber plug in the top of the stack.
 - c. With the annual maintenance audit cassettes installed, turn on the pumps, and toggle open channel #1. After the system equilibrates, the pump vacuum should be within 1”Hg of the reading with the solenoid closed, and the magnehelic reading should be 0.00”H₂O. If the system behaves differently, there's a leak.
 - d. To locate this type of leak, check the fittings between the solenoid and the top of the stack. Check each seal to be sure it is good; cassette to solenoid, cassette to manifold, black caps on manifold, magnehelic hoses(both ends of both hoses) and the brass nipple(s) they are attached to, manifold to cyclone, cyclone bottom funnel, cyclone cup, cyclone to inlet tee, inlet tee plug, and stack plug. A rarely seen, but possible cause for a leak is a cracked magnehelic face.
 - e. Remove the rubber plug from the stack.

- f. Replace the inlet on the stack.
- 2. For module D or D/S,
 - a. Remove the PM₁₀ inlet from the stack and install a rubber plug in the top of the stack.
 - b. With the annual maintenance audit cassettes installed, turn on the pumps, and toggle open channel #1. After the system equilibrates, the pump vacuum should be within 1"Hg of the reading with the solenoid closed. If it isn't, there's a leak.
 - c. To locate this type of leak, check the fittings between the solenoid and the top of the stack. Check each seal to be sure it is good; cassette to solenoid, cassette to manifold, black caps on manifold, magnehelic hoses(both ends of both hoses) and the brass nipple(s) they are attached to, manifold to funnel, funnel to stack, and the stack plug. A rarely seen, but possible cause for a leak is a cracked magnehelic face.
 - d. Remove the rubber plug from the stack.
 - e. Replace the inlet on the stack.

4.2.3.11 D Module Flow Inspection.

Verify that channels 1 and 2 in the D module are both accurately described by the system calibration equations.

1. Record the system magnehelic reading for the channel 1 and channel 2 annual maintenance audit cassettes. They should match within 0.01" H₂O. If the readings do not match, then either the orifice meter is too close to the solenoid manifold, or the path lengths between the solenoids and the orifice meter are too unequal.
 - a. If the orifice meter is not separated from the solenoid manifold brass pipe extender fitting, this should be rectified.
 - i. Turn off the sampler (turn the pump override timer or switch to "off" or "auto").
 - ii. Remove the D module orifice meter by unscrewing it from the manifold.
 - iii. Install the male end of the pipe extender fitting in the solenoid manifold, using a small amount of Teflon plumbers tape.
 - iv. Thread the male end of the orifice meter into the pipe extender.
 - v. Verify that the female end of the orifice meter is connected to the CAJON™ VCO female connector.
 - vi. Check the system for leaks, following the procedures in section 4.2.3.10.
 - vii. Turn the sampler and pumps back on using the 30 minute timer or the pump override switch.
 - viii. Test the two channels again to determine whether the readings match. If not, try step b.
 - b. If the orifice meter is separated from the manifold by the pipe extender fitting, but the readings on the two solenoids still do not match,
 - i. Turn off the sampler (turn the pump override timer or switch to "off" or "auto")

- ii. Remove one solenoid by unscrewing the two screws and nuts holding it to the solenoid manifold mounting plate. The solenoid is held in place by an o-ring fitting. Pull the solenoid straight out to remove it.
- iii. Check the o-ring on the solenoid. If it is worn or damaged, replace it. It should be lightly greased with vacuum grease.
- iv. Move the solenoid to a position on the manifold where it appears that both solenoids will be more equally spaced from the orifice meter.
- v. Install the solenoid by pressing it into position to ensure an o-ring fit, then reinstalling the screws and nuts.
- vi. Turn the sampler and pumps back on using the 30 minute timer or the pump override switch.
- vii. Check the system for leaks, following the procedures in section 4.2.3.10.
- viii. Record the readings from the two channels. If they still do not agree, perform step b again, moving the solenoids to different positions.

4.2.4 Sampler Calibration

The procedures for sampler calibration are covered in detail in TI 176C. Merely note that the final audit performed at the site shall be used to derive the calibration equation for the module.

4.2.5 Post Calibration Check

1. Perform operator training and review, as described in section 4.3.
2. Reinstall the current week's cassettes and cyclone port covers.
3. Verify that the stack bottom plugs are all securely installed.
4. Record the new initial readings for cassettes that have not yet collected a sample on the current week's log sheet. If the log sheet is not available, record the values in the site notebook, and on a sheet of paper to be left in the controller module for the site operator.
5. Start the current sample if one is supposed to be running by pressing the appropriate channel on the top row of override buttons on the clock controller. Note the restart time on the log sheet.
6. Check all fittings, stacks, inlets, etc. to verify nothing has been left out of place.
7. If the site is run by a controller module, be sure fuse is back in place.
8. Close the module doors and lock them, or lock the building in which they are kept.
9. Clean the area of the trash generated by sampler maintenance.
10. Leave a note for the site operators if they could not be contacted describing what changes were made to the site.
11. Paint the modules, if necessary, following the procedures in section 4.2.3.4 part 4.

4.3 Operator Training and Review

Site operator training involves review of the materials covered in TI 201A, IMPROVE Aerosol Sampler Operation Manual. The site operator must be trained to perform the following tasks:

1. Recording of the final readings for exposed filter cassettes.
2. Removal of exposed filter cassettes.
3. Installation of clean filter cassettes.
4. Recording of initial readings for the clean filter cassettes.
5. Mailing procedures for the return of exposed filter cassettes and log sheets.
6. Air Quality Group phone numbers; where to find them and when to call.
7. Programming the clock controller
 - a. Setting current time
 - b. Reading the installed programs
 - c. Writing new programs
 - d. Erasing unwanted programs
 - e. Where to find IMPROVE clock controller programs in the operators manual
8. Basic troubleshooting procedures for anomalous gauge readings.
9. Overview of the site audit procedure, in preparation for the biannual audit.