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NORTH CAROLINA
Environmental Quality

DAQ-07-008.1 Standard Operating Procedure (SOP)
Solar Radiation Sensor
Electronics and Calibration Branch (ECB) RESPONSIBILITIES

Revision 0

North Carolina Department of Environmental Quality | Division of Air Quality
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1.0 Approval Sign Off-Sheet

I certify that I have read and approve of the contents of the DAQ-07-008.1 Standard Operating Procedures for Solar Radiation Sensor ECB Responsibilities with an effective date of December 15, 2021.

Director, Air Quality Division

Michael Abraczinskas

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SOP Acronym Glossary

ADQ - Audit of data quality

AQS - Air Quality System (EPA's Air database)

°C – degrees Celsius

CFR – Code of Federal Regulations

Chief – Ambient Monitoring Section chief

cm – centimeter

DAQ - North Carolina Division of Air Quality

DAS – Data acquisition system

DC – Direct current

DEQ – North Carolina Department of Environmental Quality

Director – Division of Air Quality Director

ECB – Electronics and Calibration Branch

e-log – electronic logbook

EPA – United States Environmental Protection Agency

FEM – Federal equivalent method

FRM – Federal reference method

g – gram

in – inch

MDL – Method detection limit

m - meter

mm – millimeter

mV – millivolts

nm – nanometer

PM – Particulate matter

PPB – Projects and Procedures Branch

QA – Quality assurance

QA/QC - Quality assurance/quality control

QAPP - Quality assurance project plan

QC – Quality control

RCO – Raleigh central office

RH – relative humidity

SOP – Standard operating procedure

TSA – Technical systems audit

µA – microamperes

µs – microseconds

USB – universal serial bus

V – volts

Wm^{-2} or W/m^2 – Watts per meter squared

% – percent

+/- or ± – Plus, or minus

< – Less than

° – Degrees

Table of Contents

2.0 SCOPE AND PURPOSE

The purpose of this document is to describe the procedures that should be employed, at a minimum, by ECB staff and site operators for the acceptance testing, employment in the field, regular maintenance, and performance auditing of Solar Radiation Sensors for DAQ.

3.0 EQUIPMENT CHECKS AND MATERIALS

At the present time, the DAQ employs three different sensors for monitoring solar radiation. Two of these sensors are manufactured by Apogee Instruments, the model SP-212-SS Solar Radiation Sensor and the model SP-110-SS Solar Radiation Sensor, while the third is the Li-Cor Model 200r Solar Radiation Sensor. The Li-Cor model 200R and the Apogee model SP-110-SS are self-powered, while the Apogee SP-212-SS requires an external power source. These pyranometers all utilize sealed, silicon cell photodiode to convert solar radiation into electrical signal. In each case the electrical signal generated is reported in Watts/ meter squared (Wm^{-2}), and the signal strength is directly proportional to solar radiation measured. The sensors operate in the 360 to 1120 nanometer (nm) waveband and measures total global solar radiation. Each sensor employs a specially shaped lens of either cast acrylic or optical quality glass that are cosine corrected to diffuse light intensity evenly over the photodiode. The sensors are not azimuth dependent in orientation.

4.0 EQUIPMENT DESCRIPTION

Apogee SP-212-SS

• Sensitivity	1.2 millivolts (mV) / W/m^2
• Calibration Factor	0.8 W/m^2 per mV
• Calibration Uncertainty	+/- 5 percent (%)
• Output Range	0 to 2.5 volts (V)
• Repeatability	< 1 %
• Drift	< 2 % / year
• Non-Linearity	< 1 % at 200 Wm^{-2}
• Response Time	1 millisecond
• Field of View	180 degrees (°)
• Spectral Range	360- 1120 nm
• Directional Response	+/-5 % at 75 ° of zenith angle
• Temperature Response	0.04 +/- 0.04 per degree Celsius (°C)
• Operating Environment	-40 to +70 °C
• Dimensions	30.5 millimeters (mm) x 37 mm
• Mass	90 grams
• Cable	Shielded Twisted Pair
• Power Supply	5 to 24 V direct current (DC)
• Current Draw	300 microamperes (µA)

Figure 1 - Apogee Model SP-212-SS

APOGEE SP-110-SS

Sensitivity	0.2 mV / W/m^2
Calibration Factor	5 Wm^{-2} per mV
Calibration Uncertainty	+/- 5 %
Output Range	0 to 400 mV
Repeatability	< 1 %
Drift	< 2 % / year
Non-Linearity	< 1 % at 200 Wm^{-2}
Response Time	1 milliseconds
Field of View	180 °
Spectral Range	360- 1120 nm
Directional Response	+/-5 % at 75 ° of zenith angle
Temperature Response	0.04 +/- 0.04 per °C
Operating Environment	-40 to 70 °C
Dimensions	24 mm x 33 mm
Mass	90 grams
Cable	Shielded Twisted Pair

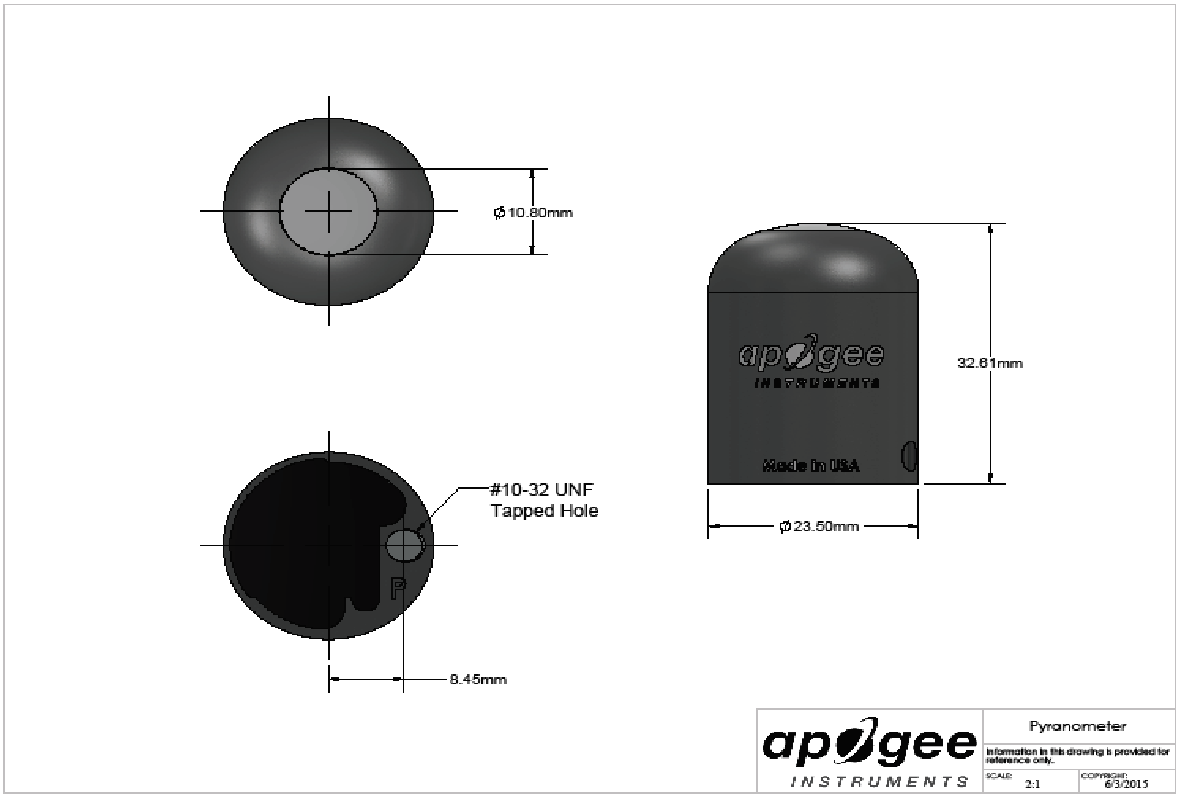

Figure 2 - APOGEE SP-110-SS

Li-Cor Li-200R

Sensitivity	Typically 75 µA per 1,000 W m^{-2}
Linearity	Maximum deviation of 1 % up to 3,000 W m^{-2}
Response Time	Less than 1 microsecond (µs) (2 meter [m] cable terminated into a 147 Ohm load)
Temperature Dependence	± 0.15% per °C maximum
Cosine Correction	Cosine corrected up to 82° angle of incidence
Azimuth	< ± 1% error over 360° at 45° elevation
Tilt	No error induced from orientation
Operating Temperature Range	−40 °C to 65 °C
Relative Humidity (RH) Range	0% to 100% RH, Non-Condensing
Detector	High stability silicon photovoltaic detector (blue enhanced)
Sensor Housing	Weatherproof anodized aluminum body with acrylic diffuser and stainless-steel hardware; O-ring seal sensor base
Size	2.36 centimeter (cm) diameter × 3.63 cm (0.93 inch [in] × 1.43 in)
Weight	24 gram (g) head; 60 g base and cable (2 m) with screws
Cable Length	Twisted Shielded Pair

Figure 3 – Li-Cor Li-200R

5.0 DESCRIPTION OF EQUIPMENT CHECKS

This section provides a description of checks to be performed on the sensor upon receipt from the manufacturer and the checks performed on the instrument prior to deployment in the field.

5.1 Shipment Inspection

The solar radiation sensor shipping container must be inspected for damage and all documents should be filed away properly. **Section 6.1** provides exact procedures for shipment inspection.

5.2 Instrument Inspection

The solar radiation sensor must be checked for functionality prior to field deployment. Typically, functionality tests include connecting the instrument to a datalogger and computer and verifying instrument response. **Section 6.2** provides detailed procedures for instrument acceptance inspection.

6.0 INITIAL STARTUP PROCEDURES

6.1 Shipment Inspection

1. Immediately upon receipt and before opening the shipping container, inspect the shipping container for any signs of damage. In the event of damage, photographs should be taken to document the state of the packaging as received. These photographs will be shared with the equipment manufacturer if the instrument is found to be damaged.
2. Upon unpacking the instrument, locate the calibration test certificate and packing slip and match the model number and serial numbers printed on the test certificate and verify all items shipped match the packing slip.
3. Initial and date the test certificate, scan it and save a scanned copy on the p-drive located here:
   P:\Ambient\SThomas\MET Equipment\Instruments Calibration Certificates\Solar Radiation Sensor Test Certificates
4. Send the packing slip to the administrative assistant.

6.2 Instrument Acceptance Inspection

1. Remove the pyranometer from the package. Visually inspect the sensor for any dents, scratches, or missing parts. Compare the unit to the relevant figure in Section 4.
2. Place the instrument on a level work bench.
3. If so equipped, carefully remove any cap covering the sensor lens. Using a soft lint free cloth carefully inspect and clean the lens.
4. Document any scratches or damage to the sensor. Note all findings in the acceptance sheet for the instrument. Avoid scratching or marring the lens on top of the instrument.
5. Mount the sensor to a solid surface using the mounting screws provided**. (Note: The solar radiation sensors are equipped with detachable head units for ease of maintenance in the field. The head units should not be detached from the base for any reason other than for return to the manufacturer for recalibration of repair. The head units are not interchangeable between manufacturers.)**
6. As the sensor contains no internal level, and lacks internal adjustments, it will be necessary for the technician to determine that the mounting surface is level. Use of a bubble level is recommended for this task. Leveling plates or mounting brackets are commercially available, and recommended, for use in mounting the sensor. For best response the sensor must be level.
7. Orient the sensor so that the attached cable is pointing toward true north to minimize any azimuth errors. For field mountings, the technician should at this time make sure that no obstruction shades the sensor or occludes the lens.
8. Test sensor functionality using the supplied weatherproof cabling or a shielded, twisted pair cable. Connect the cable to the sensor and to a datalogger (**as described in Section 6.3**) or a voltmeter capable of measuring and displaying or recording signal in the range of 0- 250 mV. This input measurement range is required to cover the entire shortwave radiation spectrum from the sun. For maximum measurement resolution, the input range of the measurement device should closely match the output range of the sensor**. (Note: All of the sensors are provided with a three wire cable for hook up. Please refer to the instructions enclosed with the sensor for proper wiring instructions.)**
9. Connect the logger to the MetOne 10600 Module as described in **Section 6.3** below.

10. Program the data logger to convert millivolts to Wm^{-2}. (Raw signal x calibration factor = Wm^{-2})
11. Setup a solar radiation channel in the **Envidas SETUP** program to capture intensities transmitted by the data logger. Save your settings and restart the **Envidas SETUP program**.
12. Open **Envidas VIEWER** to see instant reading from the solar radiation sensor.
13. Expose the sensor to a light source emitting in the visible spectrum. Ideally, functionality should be tested in direct sunlight. If operating properly, the 10600 data module should display a value proportional to the intensity of the light source. Remove the light source and cover the sensor lens with some opaque material. The 10600 data module should read zero. If using a voltmeter, current from the sensor should drop to zero.
14. Record results of all tests on acceptance sheet. Include data module or voltmeter readings. If sensor passes acceptance tests it is ready for deployment in the field. If sensor fails tests, the manufacturer should be contacted to facilitate repairs or return of the sensor.

6.3 MetOne model 10600 Data Module Installation and Set Up (for sites with collocated met sensors):

6.3.1 MET Module

1. Open the MetOne 10600 data module cover by removing the 4 screws located on top of the unit.
2. Using RS232 cable, connect AIO2 to terminal TB1 on model 10600.

6.3.2 Solar Radiation Sensor

1. Connect solar radiation sensor to terminal **TB7** on model 10600 using RS232 cable.
2. Connect the purple wire from the data cable from the AIO2 to Solar Radiation terminal **TB9** of model 10600 module (refer to the manufacturer manual if needed).
3. Connect the RS232 data cable from the computer to the RS232 connector on the MetOne model 10600 module. Note the COM port number assigned, this will be required to link the module to the computer/software network.
4. Set **SW1** to **on** from the model 10600 module to position **C1** RS232.
5. Connect 12 V power supply that came with the unit.

6.3.3 Comet 2 Setup to read MET data via 10600 Data Module

1. Connect RS232/Universal Serial Bus (USB) from 10600 Module to desired **COM PORT** in Comet 2.
2. Check continuity via Device Manager to confirm chosen **COM PORT** number.
3. On site computer, open Comet 2 software.
4. Add Module:
   - **Select** the **Ξ** icon on top left of screen
   - Click on **add new station**
   - Click **MET** and click **<next>**
   - Click **digital sensor (MSD, AIO2, 597)** and click **<next>**
   - Select serial port and click **<next>**
   - From Drop Down Menu select COMM PORT and click **<next>**
   - Enter station name and click **finish**
   - **Click** the Terminal Icon

   <u>Note: Envidas COMM PORT must be disabled before programming model 10600 module and then must be enabled before proceeding</u>

   - Press **enter** at least three times until asterisk symbol appears (*)
   - Enter **0i1** and press **enter**

6.4 Advantech ADAM 5000TCP Module Setup with Solar Radiation Sensor

For sites that do not utilize an above data transmission protocol, an Advantech ADAM 5000TCP Module can be used instead. This is a cost-effective option when only solar radiation is to be measured.

1. Download the AdamApax .Net Utility software for ADAM/APAX series software onto your computer.
2. Run the software and accept its license agreement.
3. Install the ADAM 2017 Module onto slot '0' on the ADAM 5000L/TCP Ethernet logger.
4. Use the blank cover to cover the remaining slots on the ADAM 5000L/TCP.
5. Connect the Apogee Solar Radiation Sensor wires to the ADAM 2017 Slot V0+ (Red) and Slot V0- (Black).
6. Connect one end of the Ethernet cable onto DATA+ / DATA- slot on the ADAM 5000L/TCP module and the other end to the Internet Router.
7. Connect the 12-volt power supply that comes with the ADAM 5000L/TCP module.
8. Power On the Module.
9. On your computer, click and open the ADAM/APAX series software.
10. Select the Ethernet link.
11. Click **< Tools >** on the menu bar, and the click **< Search Device >**. The box below, in Figure 4, will be displayed. **< Search Device >** will recognize the ADAM equipment and will display its information.

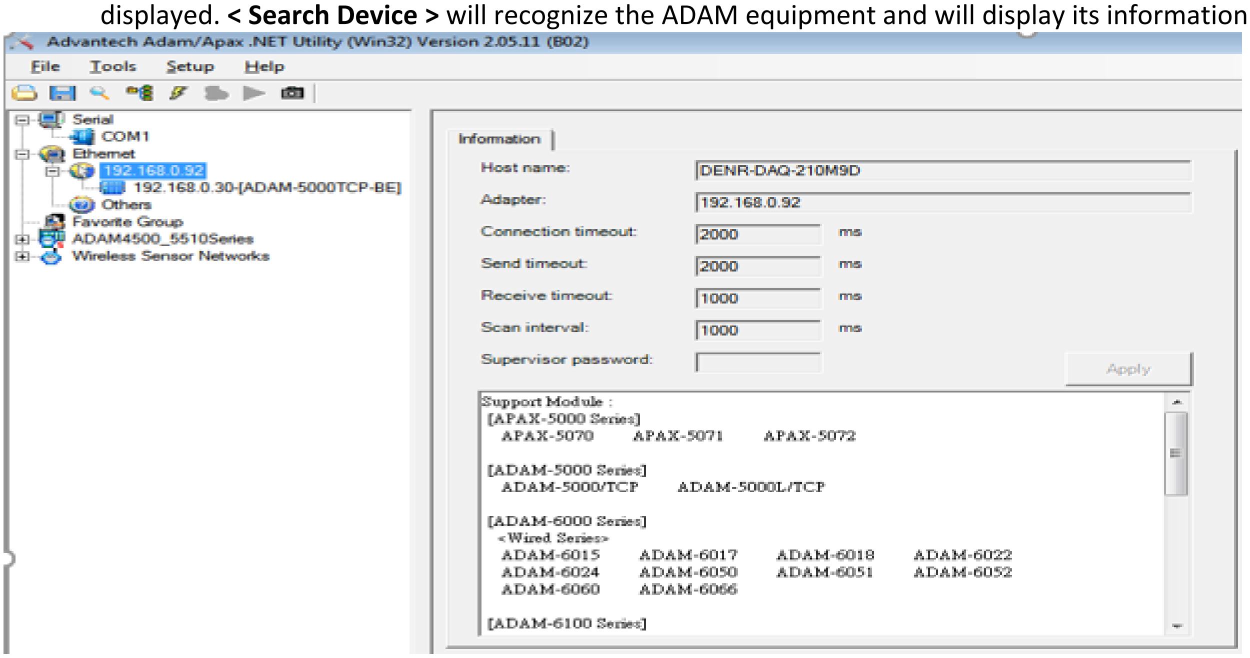

Figure 4 - ADAM/Apax.Net Utility <Search Device> Example

12. Click **< 5017(SO) >** tab on the left side of the screen, it will ask for a password, type in 00000000 and press **< Enter >** to access the sensor.
13. Select the **RS-485/WDT** tab and enter the port settings as shown below in Figure 5:

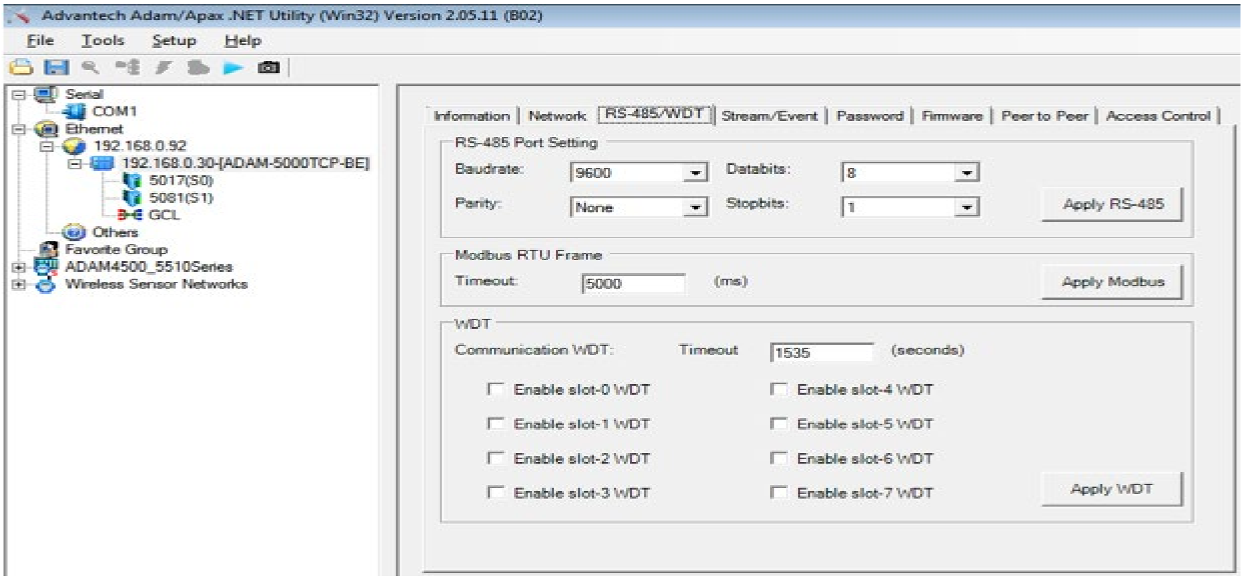

Figure 5 - Solar Radiation Sensor RS-485/WDT Port Settings.

14. Click **Apply RS-485**.
15. Click the **Stream/Event** tab and enter a value of 1 second into the **Data Streaming** tab to establish a sending interval as shown in Figure 6.

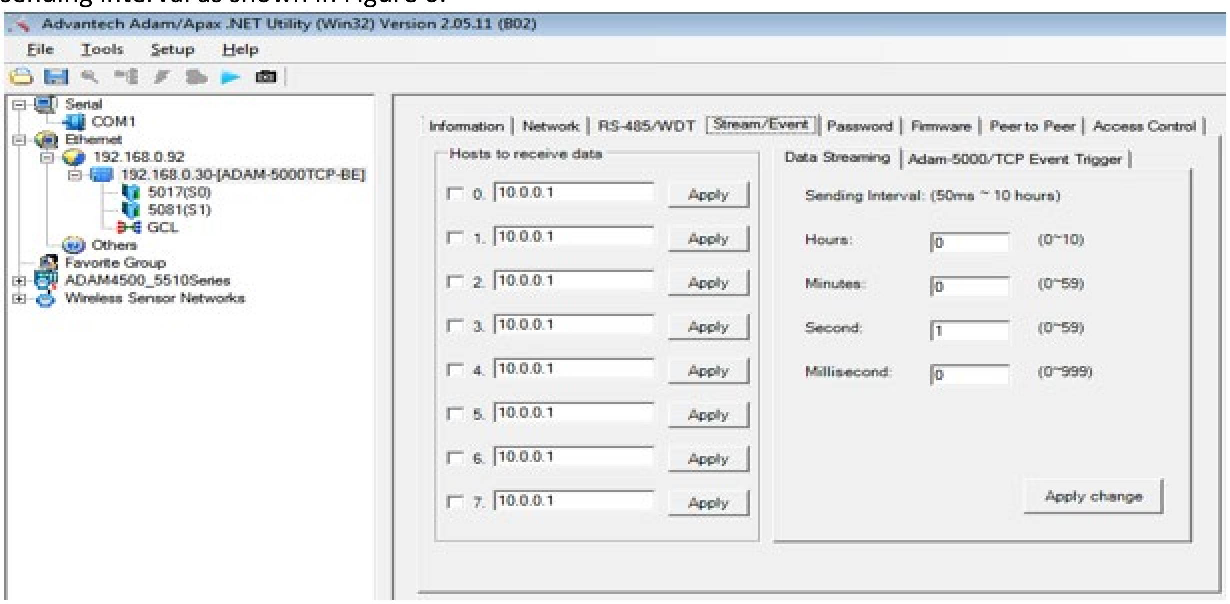

Figure 6 - Solar Radiation Sensor Stream/Event Configuration

16. Click **Apply change** to set the data streaming sending interval. Please note the **Password, Firmware, Peer to Peer,** and **Access Control** were all left blank or at default settings.

7.0 SITE INSTALLATION

1. The chosen site for installation must adhere to siting criteria listed in the EPA Volume IV handbook.

2. The sensor should be located so that (a) no shadows will be cast on it anytime; (b) it is not too close to light-colored walls or other objects likely to reflect sunlight onto it; and (c) it is not exposed to artificial radiation sources.
3. Mount the instrument on a solid, sturdy, and level surface, paying special attention that nothing obstructs sunlight to the sensor.
4. Securely attach sensor to a mounting stand using the hole provided in the instrument's baseplate and the included nylon screw. Ensure that the sensor is oriented so that the attached cable is pointing toward true north. The mounting position selected for the sensor should be sufficiently rigid to prevent the horizontal position of the instrument from moving, especially in high winds.
5. Follow steps 6-14 in **Section 6.2, and Section 6.3** to connect the instrument to the datalogger, site computer, and Envidas SETUP.
6. Record the site installation details in the site logbook. Fill out and sign an AQ-109 form, give a copy of the signed form to the ECB supervisor for signature and retention.

8.0 ROUTINE MAINTENANCE

Additional routine maintenance items may include, grass cutting, pest control, cleaning the mesh screens, cleaning gauge surfaces with water, visually checking wire condition and connections outside of the gauge, but at a minimum a technician should conduct the following:

8.1 Regular Maintenance

On a monthly basis, or more often, if necessary, a technician should:

1. Inspect the sensor for any damage.
2. Carefully clean the lens by wiping gently with a soft, lint free cloth.
3. Check the instrument's level to ensure the sensor has not moved. If the sensor requires fine adjustment to regain level, the technician may adjust the mounting plate until the plate is level. In this case note should be made in the site logbook and the ECB contacted for further instructions.

8.2 Instrument Performance Checks

At least every six months, or more often, if necessary, an ECB technician must:

1. Verify that conditions for Onsite Installation #1 and #2 outlined above are still applicable to the sensor. Document the results of the check and place in the site logbook and e-log. Immediately contact ECB supervisor if conditions for the checks have changed.
2. Perform a field functionality test to determine if the sensor is operating correctly. Field functionality tests should follow the directions listed in **Section 6.2 #13**, as discussed above. The results of the functionality tests should be documented in the appropriate maintenance logbook, the site logbook, and the e-log for one of the instruments at the site.
3. Sensors that fail field functionality tests must be immediately removed from the field and returned to the manufacturer for repair, recalibration, or recertification as necessary.

9.0 ACCURACY AUDITS

Both the Apogee and Li-Cor Pyranometers currently in use come calibrated from the factory. No field calibration or adjustment should be attempted. At least once every 3 calendar years, or immediately upon a failed field functionality test attributable to the sensor, the sensor should be returned to the manufacturer for calibration and recertification. Copies of all recertification records should be retained, and copies placed in the sensor specific maintenance logbook.

10.0 REVISION HISTORY

1. 9/15/2021 **ML –** Initial Publication

11.0 REFERENCES

1. United States Environmental Protection Agency: Office of Air Quality Planning and Standards (2008). Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV: Meteorological Measurements. Version 2.0. Research Triangle Park, NC. Mikel, Dennis; Landreneua, Joey; Fields, Daniel; Bush, David; Fransiola, Paul; Eagan, Tammy; Field, Kent; Baxter, Bob; Dye, Tim; Acemount, Gary and Heffern, Richard.

12.0 APPENDICES

1. Appendix A – Solar Radiation Audit Form
2. Appendix B – AQ-109 Form

Appendix A – Solar Radiation Audit Form

DAQ-07-015.1 Solar Radiation Audit Revision 0

Data Logger SN					
Site		Date			
Start Time		Stop Time			
Audit Sensor Model		Audit Sensor SN		Exp. Date	
Site Sensor Model		Site Sensor SN			

Test	Audit Sensor Solar Radiation Reading (W/m2)	Site Sensor and Data logger Solar radiation reading (W/m2)	Difference	% Diff ± 5 %
Test 1			**#DIV/0!**	**#DIV/0!**
Test 2			**#DIV/0!**	**#DIV/0!**
Test 3			**#DIV/0!**	**#DIV/0!**

Acceptable:	Yes		No		Auditor	
					Calibrator	

If any point above fails. Clean site sensor surface and perform test again using space below.

Site Sensor Model		Site Sensor SN	

Test	Audit Sensor Solar Radiation Reading (W/m2)	Site Sensor and Data logger Solar radiation reading (W/m2)	Difference	% Diff ± 5 %
Test 1			**#DIV/0!**	**#DIV/0!**
Test 2			**#DIV/0!**	**#DIV/0!**
Test 3			**#DIV/0!**	**#DIV/0!**

Acceptable:	Yes		No		Auditor	
					Calibrator	

If any point fails again, replace site sensor with freshly calibrated sensor and perform test again using space below

Site Sensor Model		Site Sensor SN	

Test	Audit Sensor Solar Radiation Reading (W/m2)	Site Sensor and Data logger Solar radiation reading (W/m2)	Difference	% Diff ± 5 %
Test 1			**#DIV/0!**	**#DIV/0!**
Test 2			**#DIV/0!**	**#DIV/0!**
Test 3			**#DIV/0!**	**#DIV/0!**

Acceptable:	Yes		No	

Auditor	
Calibrator	

Comments:

Appendix B – AQ-109 Audit Form

AIR QUALITY SECTION
MAINTENANCE ORDER

Region: ____________ Site: ______________________________ Date of Service: ____________

Requested By: ____

Action Requested: Repair _____ Supply _____ Maintain _____ Audit _____ Installation _____ Removal ______

Requested Action: ____

____

____

____

____

Action Taken (Shop Use Only): ____

____

____

____

____

____

Parts Used: ____

____

____

____

____

Cylinders (Installed):

Cylinder: Type _________ PPM ______ SN __________________ PSI _______ Expires ___________

Cylinder: Type _________ PPM ______ SN __________________ PSI _______ Expires ___________

Cylinders (Removed):

Cylinder: Type _________ PPM ______ SN __________________ PSI _______ Expires ___________

Cylinder: Type _________ PPM ______ SN __________________ PSI _______ Expires ___________

Travel Time: Departed: __________________ AM PM Returned: __________________ AM PM

Vehicle (1): ______________________________ Vehicle (2): ______________________________

Vehicle Number: ___________________________ Vehicle Number: ___________________________

Logbook(s) Updated: YES NO N/A Comment(s): ____

Comment(s): ____

____

____

____

Date Signed: __________ Technician(s): ______________________________ Supervisor's Initials ____

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