



OWNER'S MANUAL

UNDERWATER EPAR METER

Models MQ-650

Rev: 2-Jul-2021



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CERTIFICATE OF COMPLIANCE

EU Declaration of Conformity

This declaration of conformity is issued under the sole responsibility of the manufacturer:

Apogee Instruments, Inc.
721 W 1800 N
Logan, Utah 84321
USA

for the following product(s):

Models: MQ-650
Type: ePAR Meter

The object of the declaration described above is in conformity with the relevant Union harmonization legislation:

2014/30/EU Electromagnetic Compatibility (EMC) Directive
2011/65/EU Restriction of Hazardous Substances (RoHS 2) Directive
2015/863/EU Amending Annex II to Directive 2011/65/EU (RoHS 3)

Standards referenced during compliance assessment:

EN 61326-1:2013 Electrical equipment for measurement, control and laboratory use – EMC requirements
EN 50581:2012 Technical documentation for the assessment of electrical and electronic products with respect to
the restriction of hazardous substances

Please be advised that based on the information available to us from our raw material suppliers, the products manufactured by us do not contain, as intentional additives, any of the restricted materials including lead (see note below), mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB), polybrominated diphenyls (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP). However, please note that articles containing greater than 0.1% lead concentration are RoHS 3 compliant using exemption 6c.

Further note that Apogee Instruments does not specifically run any analysis on our raw materials or end products for the presence of these substances, but rely on the information provided to us by our material suppliers.

Signed for and on behalf of:
Apogee Instruments, July 2021



Bruce Bugbee
President
Apogee Instruments, Inc.

INTRODUCTION

Radiation that drives photosynthesis is called photosynthetically active radiation (PAR) and, historically, is defined as total radiation across a range of 400 to 700 nm. PAR is almost universally quantified as photosynthetic photon flux density (PPFD) in units of micromoles per square meter per second ($\mu\text{mol m}^{-2} \text{s}^{-1}$, equal to microEinsteins per square meter per second) summed from 400 to 700 nm (total number of photons from 400 to 700 nm). However, ultraviolet and far-red photons outside the defined PAR range of 400-700 nm can also contribute to photosynthesis and influence plant responses (e.g., flowering).

Sensors that measure PPFD are often called quantum sensors due to the quantized nature of radiation. A quantum refers to the minimum quantity of radiation, one photon, involved in physical interactions (e.g., absorption by photosynthetic pigments). In other words, one photon is a single quantum of radiation. Sensors that function like traditional quantum sensors, but measure a wider range of wavelengths can be thought of as an 'extended range' quantum sensor.

Typical applications of traditional quantum sensors include incoming PPFD measurement over plant canopies in outdoor environments or in greenhouses and growth chambers, and reflected or under-canopy (transmitted) PPFD measurement in the same environments. The extended photosynthetically active radiation (ePAR) sensor detailed in this manual uses a detector that is sensitive to radiation from 380-760 nm, which allows it to measure photons from UV and Far-red.

Quantum sensors are increasingly used to measure PFD underwater, which is important for biological, chemical, and physical processes in natural waters and in aquariums. When a quantum sensor that was calibrated in air is used to make underwater measurements, the sensor reads low. This phenomenon is called the immersion effect and happens because the refractive index of water (1.33) is greater than air (1.00). The higher refractive index of water causes more light to be backscattered (or reflected) out of the sensor in water than in air (Smith,1969; Tyler and Smith,1970). As more light is reflected, less light is transmitted through the diffuser to the detector, which causes the sensor to read low. Without correcting for this effect, underwater measurements are only relative, which makes it difficult to compare light in different environments. The immersion effect correction factor for Apogee ePAR sensors (model MQ-610 and SQ-610 series) is 1.25. The MQ-650 ePAR meter is designed for underwater measurements, and already applies the immersion effect correction factor to the meter's readings through firmware. The meter consists of a waterproof quantum sensors attached via waterproof cable to a handheld meter. **Note: The handheld meter is not waterproof, only the sensor and cable are waterproof.**

Apogee Instruments MQ-650 meters consist of a handheld meter and a dedicated sensor that is connected by cable to an anodized aluminum housing. SQ-600 series ePAR sensors consist of a cast acrylic diffuser (filter), photodiode, signal processing circuitry mounted in an anodized aluminum housing, and are potted solid with no internal air space. MQ series ePAR meters provide a real-time PFD reading on the LCD display, that determine the radiation incident on a planar surface (does not have to be horizontal), where the radiation emanates from all angles of a hemisphere. MQ series ePAR meters include manual and automatic data logging features for making spot-check measurements or calculating daily light integral (DLI).

SENSOR MODELS

Apogee MQ series ePAR meters covered in this manual are self-contained and come complete with handheld meter and sensor.

Model MQ-650

Serial # 0000

Intended for use under all
light sources

Range: 380 - 760 nm

apogeeinstruments.com

Made in USA



Push **mode** to scroll through options;
use **arrows** to select options.

In sample mode **sample** records data
and **arrows** review stored data.

Sensor model number and serial number are
located on a label on the backside of the handheld
meter.

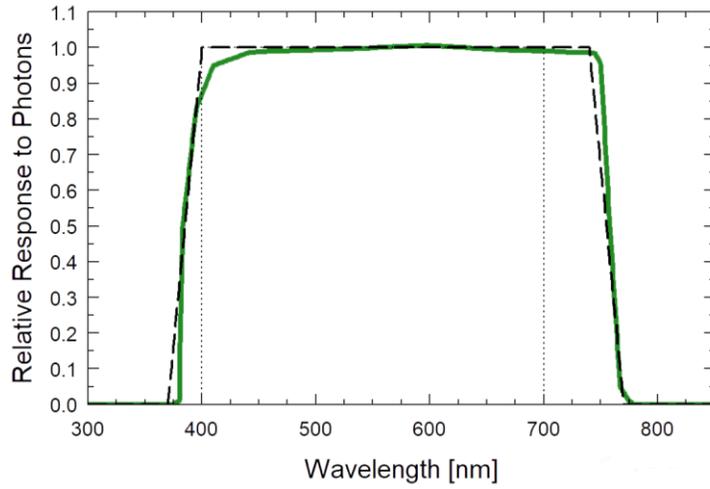
SPECIFICATIONS

MQ-650	
Calibration Uncertainty	± 5 % (see calibration Traceability below)
Measurement Range	0 to 4000 $\mu\text{mol m}^{-2} \text{s}^{-1}$
Measurement Repeatability	Less than 0.5 %
Long-term Drift (Non-stability)	Less than 2 % per year
Non-linearity	Less than 1 % (up to 4000 $\mu\text{mol m}^{-2} \text{s}^{-1}$)
Response Time	Less than 1 ms
Field of View	180°
Spectral Range	380 to 760 nm ± 5 nm (wavelengths where response is greater than 50 %)
Directional (Cosine) Response	± 5 % at 75° zenith angle (see Cosine Response below)
Azimuth Error	Less than 0.5 %
Tilt Error	Less than 0.5 %
Temperature Response	-0.11 ± 0.04 % per C (see Temperature Response below)
Uncertainty in Daily Total	Less than 5 %
Detector	Blue-enhanced silicon photodiode
Housing	Anodized aluminum body with acrylic diffuser
IP Rating	IP68
Operating Environment	0 to 50 C; less than 90 % non-condensing relative humidity up to 30 C; less than 70 % non-condensing relative humidity from 30 to 50 C; separate sensors can be submerged in water up to depth of 30 m
Meter Dimension	126 mm length; 70 mm width; 24 mm height
Sensor Dimensions	30.5 mm diameter; 37 mm height
Mass	100 g (with 5 m of lead wire)
Cable	2 m of two conductor, shielded, twisted-pair wire; additional cable available; TPR jacket

Calibration Traceability

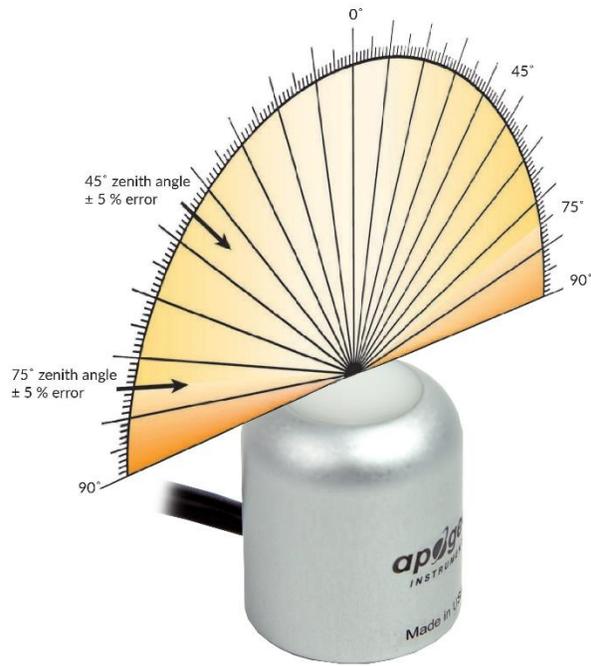
Apogee MQ series ePAR meters are calibrated through side-by-side comparison to the mean of four transfer standard sensors under a reference lamp. The reference sensors are recalibrated with a 200 W quartz halogen lamp traceable to the National Institute of Standards and Technology (NIST).

Spectral Response

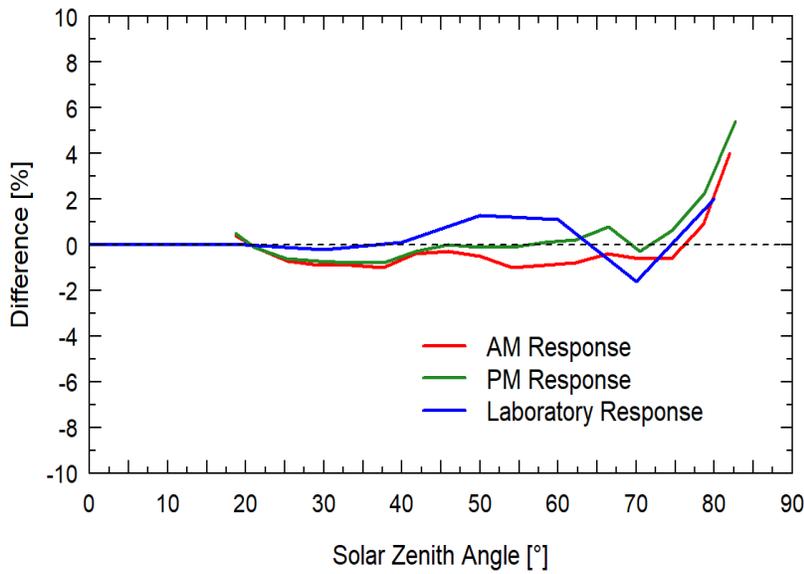


Mean spectral response measurements of four replicate Apogee MQ-600 series ePAR Sensors. Incremental spectral response measurements were made at 10 nm increments across a wavelength range of 370 to 800 nm in a monochromator with an attached electric light source. Measured spectral data from each quantum sensor were refined and normalized by comparing measured spectral response of the monochromator/electric light combination to measured spectral differences from a quantum sensor reference.

Cosine Response



Directional, or cosine, response is defined as the measurement error at a specific angle of radiation incidence. Error for Apogee MQ-600 series ePAR Sensor is approximately ± 2 % and ± 5 % at solar zenith angles of 45° and 75°, respectively.



Mean directional (cosine) response of seven Apogee series quantum sensors. Directional response measurements were made on the rooftop of the Apogee building in Logan, Utah. Directional response was calculated as the relative difference of quantum sensors from the mean of replicate reference quantum sensors (LI-COR models LI-190 and LI-190R, Kipp & Zonen model PQS 1). Data were also collected in the laboratory using a reference lamp and positioning the sensor at varying angles.

DEPLOYMENT AND INSTALLATION

Apogee MQ series ePAR meters are designed for spot-check measurements, and calculation of daily light integral (DLI; total number of photons incident on a planar surface over the course of a day) through the built-in logging feature. To accurately measure PFD incident on a horizontal surface, the sensor must be level. The AL-100 accessory leveling plate is recommended for use with the MQ-650 to ensure the sensor is level when attached to a cross-arm. The bubble-level in the plate makes leveling simple and accurate.



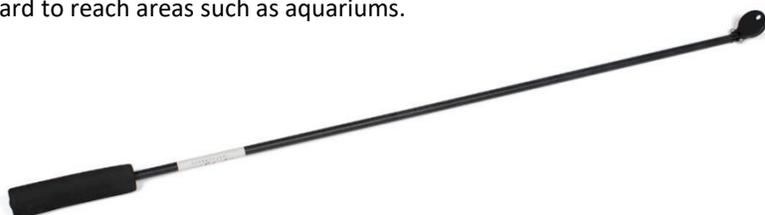
MQ-650 sensor attached to an AL-100 leveling plate.

The AM-310 Sensor Wand accessory incorporates a mounting fixture at the end of an extendable telescopic wand (up to 33 inches/84 cm). The wand is not suited for wet environments; however, it is excellent for greenhouses and growth chambers. Its ability to retract to a smaller size also makes it ideal for travel use.



AM-310 Extendable Sensor Wand

The AM-320 Saltwater Submersible Sensor Wand accessory incorporates a mounting fixture at the end of a 40 inch segmented fiberglass wand and is well-suited for saltwater use. The wand allows the user to place the sensor in hard to reach areas such as aquariums.

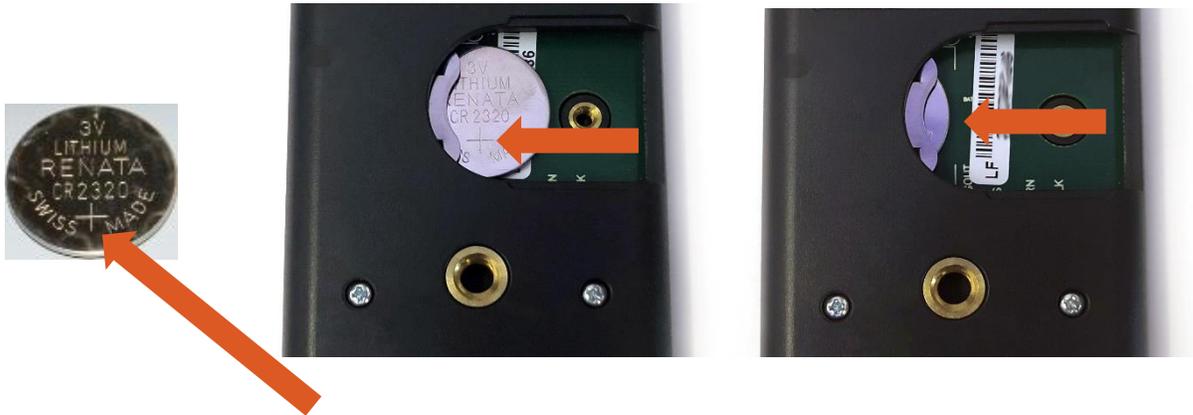


AM-320 Saltwater Submersible Sensor Wand

BATTERY INSTALLATION AND REPLACEMENT

Use a phillips head screwdriver to remove the screw from the battery cover. Remove the battery cover by slightly lifting and sliding the outer edge of the cover away from the meter.

To power the meter, slide the included battery (CR2320) into the battery holder, after removing the battery door from the meter's back panel.



The positive side (designated by a "+" sign) should be facing out from the meter circuit board.

NOTE: The battery cradle can be damaged by using an incorrectly sized battery. If the battery cradle is damaged, the circuit board will need to be replaced. To avoid this costly problem, use only a CR2320 battery.

Battery Removal

Press down on the battery with a screwdriver or similar object. Slide battery out.



If the battery is difficult to move, turn the meter on its side so that the opening for the battery is facing downward and tap the meter downward against an open palm to dislodge the battery enough so that it can be removed with your thumb to slide the battery out of the battery holder.

OPERATION AND MEASUREMENT

MQ series ePAR meters are designed with a user-friendly interface allowing quick and easy measurements.



Press the power button to activate the LCD display. After two minutes of non-activity the meter will revert to sleep mode and the display will shut off to conserve battery life.



Press the mode button to access the main menu, where manual or automatic logging are selected, and where the meter can be reset.



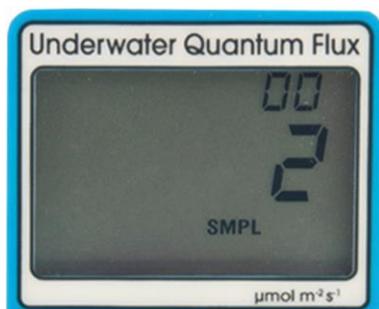
Press the sample button to log a reading while taking manual measurements.



Press the up button to make selections in the main menu. This button is also used to view and scroll through the logged measurements on the LCD display.



Press the down button to make selections in the main menu. This button is also used to view and scroll through the logged measurements on the LCD display.



The LCD display consists of the total number of logged measurements in the upper right hand corner, the real-time PPF value in the center, and the selected menu options along the bottom.

Logging: To choose between manual or automatic logging, push the mode button once and use the up/down buttons to make the appropriate selection (SMPL or LOG). Once the desired mode is blinking, press the mode button two more times to exit the menu. When in SMPL mode press the sample button to record up to 99 manual measurements (a counter in the upper right hand corner of the LCD display indicates the total number of saved measurements). When in LOG mode the meter will power on/off to make a measurement every 30 seconds. Every 30 minutes the meter will average the sixty 30 second measurements and record the averaged value to memory. The meter can store up to 99 averages and will start to overwrite the oldest measurement once there are 99 measurements. Every 48 averaged measurements (making a 24 hour period), the meter will also store an integrated daily total in moles per meter squared per day ($\text{mol m}^{-2} \text{d}^{-1}$).

Reset: To reset the meter, in either SMPL or LOG mode, push the mode button three times (RUN should be blinking), then while pressing the down button, press the mode button once. This will erase all of the saved measurements in memory, but only for the selected mode. That is, performing a reset when in SMPL mode will only erase the manual measurements and performing a reset when in LOG mode will only erase the automatic measurements.

Review/Download Data: Each of the logged measurements in either SMPL or LOG mode can be reviewed on the LCD display by pressing the up/down buttons. To exit and return to the real-time readings, press the sample button. Note that the integrated daily total values are not accessible through the LCD and can only be viewed by downloading to a computer.

Downloading the stored measurements will require the AC-100 communication cable and software (sold separately). The meter outputs data using the UART protocol and requires the AC-100 to convert from UART to USB, so standard USB cables will not work. Set up instructions and software can be downloaded from the Apogee website (<http://www.apogeeinstruments.com/ac-100-communication-cable/>).

(SMPL) 99 Sample Measurements	(LOG) 99 Log Measurements	(LOG) 99 Daily Total Measurements
Viewable on meter LCD & downloadable		Downloadable Only

Immersion Effect Correction Factor

When a radiation sensor is submerged in water, more of the incident radiation is backscattered out of the diffuser than when the sensor is in air (Smith, 1969; Tyler and Smith, 1970). This phenomenon is caused by the difference in the refractive index for air (1.00) and water (1.33), and is called the immersion effect. Without correction for the immersion effect, radiation sensors calibrated in air can only provide relative values underwater (Smith, 1969; Tyler and Smith, 1970). Immersion effect correction factors can be derived by making measurements in air and at multiple water depths at a constant distance from a lamp in a controlled laboratory setting.

The MQ-650 sensor has an immersion effect correction factor of 1.25. The immersion effect correction factor is already accounted for in the MQ-650 meter firmware so there is no need to apply the correction factor to your measurements. If you wish to use your meter to make measurements in air, simply divide the measured number by the immersion effect (1.25).

When making underwater measurements, only the sensor and cable can go in the water. The handheld meter is not waterproof and must not get wet. If the meter might get wet from splashing, we recommend placing it in a plastic bag or other container to help protect it from accidentally getting wet.

Further information on underwater measurements and the immersion effect can be found on the Apogee webpage (<http://www.apogeeinstruments.com/underwater-par-measurements/>).

Smith, R.C., 1969. An underwater spectral irradiance collector. *Journal of Marine Research* 27:341-351.

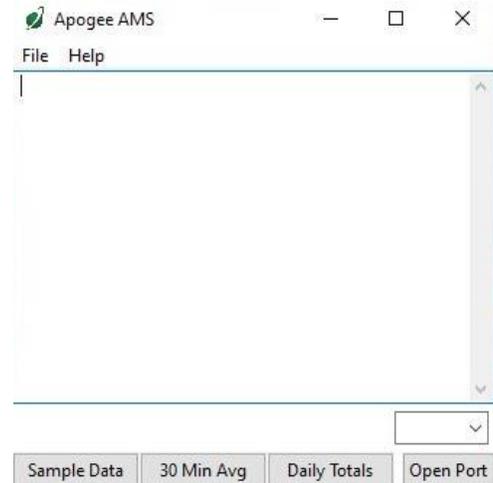
Tyler, J.E., and R.C. Smith, 1970. *Measurements of Spectral Irradiance Underwater*. Gordon and Breach, New York, New York. 103 pages.

APOGEE AMS SOFTWARE

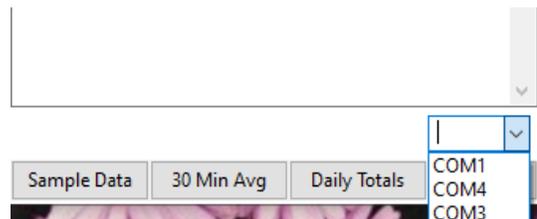
Downloading data to a computer requires the [AC-100 communication cable](#) and the free ApogeeAMS software. The meter outputs data using the UART protocol and requires the AC-100 to convert from UART to USB, so standard USB cables will not work.

The most recent version of ApogeeAMS software can be downloaded at <http://www.apogeeinstruments.com/downloads/>.

When the ApogeeAMS software is first opened, it will show a blank screen until communication with the meter is established. If you click “Open Port” it will say “connection failed.”

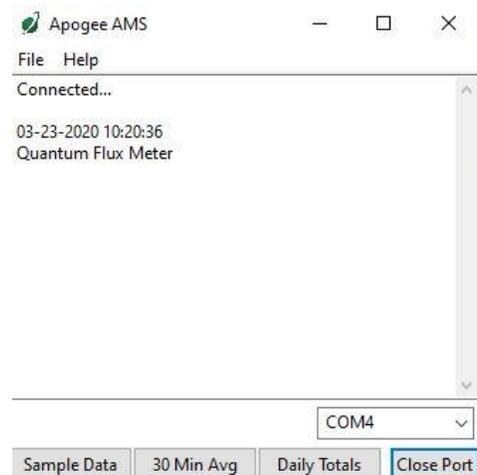


To establish communication, make sure the meter is plugged into your computer using the AC-100 communication cable. To connect click the dropdown menu button and “COM#” options will appear. For more details on how to figure out which COM is the right one, [watch our video](#).



When you have connected to the correct COM#, the software will say “Connected”.

Click “Sample Data” to view saved sample readings.



MAINTENANCE AND RECALIBRATION

Moisture or debris on the diffuser is a common cause of low readings. The sensor has a domed diffuser and housing for improved self-cleaning from rainfall, but materials can accumulate on the diffuser (e.g., dust during periods of low rainfall, salt deposits from evaporation of sea spray or sprinkler irrigation water) and partially block the optical path. Dust or organic deposits are best removed using water or window cleaner and a soft cloth or cotton swab. Salt deposits should be dissolved with vinegar and removed with a soft cloth or cotton swab. **Never use an abrasive material or cleaner on the diffuser.**

Although Apogee sensors are very stable, nominal accuracy drift is normal for all research-grade sensors. To ensure maximum accuracy, we generally recommend sensors are sent in for recalibration every two years, although you can often wait longer according to your particular tolerances.

TROUBLESHOOTING AND CUSTOMER SUPPORT

Verify Functionality

Pressing the power button should activate the LCD and provide a real-time PPF_D reading. Direct the sensor head toward a light source and verify the PPF_D reading responds. Increase and decrease the distance from the sensor to the light source to verify that the reading changes proportionally (decreasing PPF_D with increasing distance and increasing PPF_D with decreasing distance). Blocking all radiation from the sensor should force the PPF_D reading to zero.

Battery Life

When the meter is maintained properly the coin cell battery (CR2320) should last for many months, even after continuous use. The low battery indicator will appear in the upper left hand corner of the LCD display when the battery voltage drops below 2.8 V DC. The meter will still function correctly for some time, but once the battery is drained the pushbuttons will no longer respond and any logged measurements will be lost.

Pressing the power button to turn off the meter will actually put it in sleep mode, where there is still a slight amount of current draw. This is necessary to maintain the logged measurements in memory. Therefore, it is recommended to remove the battery when storing the meter for many months at a time, in order to preserve battery life.

Low-Battery Error after Battery Replacement

A master reset will usually correct this error, please see the master reset section for details and cautions. If a master reset does not remove the low battery indicator, please double check that the voltage of your new battery is above 2.8 V, this is the threshold for the indicator to turn on.

Master Reset

If a meter ever becomes non-responsive or experiences anomalies, such as a low battery indicator even after replacing the old battery, a master reset can be performed that may correct the problem. Note that a master reset will erase all logged measurements from memory.

Step 1: press the power button so that the LCD display is activated.

Step 2: Slide the battery out of the holder, which will cause the LCD display to fade out.

Step 3: After a few seconds, slide the battery back into the holder.

The LCD display will flash all segments and then show a revision number (e.g. "R1.0"). This indicates the master reset was performed and the display should return to normal.

Error Codes and Fixes

Error codes will appear in place of the real-time reading on the LCD display and will continue to flash until the problem is corrected. Contact Apogee if the following fixes do not rectify the problem.

Err 1: battery voltage out of range. **Fix:** replace CR2320 battery and perform master reset.

Err 2: sensor voltage out of range. **Fix:** perform master reset.

Err 3: not calibrated. **Fix:** perform master reset.

Err 4: CPU voltage below minimum. **Fix:** replace CR2320 battery and perform master reset.

Modifying Cable Length

Although it is possible to splice additional cable to the separate sensor of the appropriate MQ model, note that the cable wires are soldered directly into the circuit board of the meter. Care should be taken to remove the back panel of the meter in order to access the board and splice on the additional cable, otherwise two splices would need to be made between the meter and sensor head. See Apogee webpage for further details on how to extend sensor cable length: (<http://www.apogeeinstruments.com/how-to-make-a-weatherproof-cable-splice/>).

RETURN AND WARRANTY POLICY

RETURN POLICY

Apogee Instruments will accept returns within 30 days of purchase as long as the product is in new condition (to be determined by Apogee). Returns are subject to a 10 % restocking fee.

WARRANTY POLICY

What is Covered

All products manufactured by Apogee Instruments are warranted to be free from defects in materials and craftsmanship for a period of four (4) years from the date of shipment from our factory. To be considered for warranty coverage an item must be evaluated by Apogee.

Products not manufactured by Apogee (spectroradiometers, chlorophyll content meters, EE08-SS probes) are covered for a period of one (1) year.

What is Not Covered

The customer is responsible for all costs associated with the removal, reinstallation, and shipping of suspected warranty items to our factory.

The warranty does not cover equipment that has been damaged due to the following conditions:

1. Improper installation or abuse.
2. Operation of the instrument outside of its specified operating range.
3. Natural occurrences such as lightning, fire, etc.
4. Unauthorized modification.
5. Improper or unauthorized repair.

Please note that nominal accuracy drift is normal over time. Routine recalibration of sensors/meters is considered part of proper maintenance and is not covered under warranty.

Who is Covered

This warranty covers the original purchaser of the product or other party who may own it during the warranty period.

What Apogee Will Do

At no charge Apogee will:

1. Either repair or replace (at our discretion) the item under warranty.
2. Ship the item back to the customer by the carrier of our choice.

Different or expedited shipping methods will be at the customer's expense.

How To Return An Item

1. Please do not send any products back to Apogee Instruments until you have received a Return Merchandise

Authorization (RMA) number from our technical support department by submitting an online RMA form at www.apogeeinstruments.com/tech-support-recalibration-repairs/. We will use your RMA number for tracking of the service item. Call (435) 245-8012 or email techsupport@apogeeinstruments.com with questions.

2. For warranty evaluations, send all RMA sensors and meters back in the following condition: Clean the sensor's exterior and cord. Do not modify the sensors or wires, including splicing, cutting wire leads, etc. If a connector has been attached to the cable end, please include the mating connector – otherwise the sensor connector will be removed in order to complete the repair/recalibration. **Note:** *When sending back sensors for routine calibration that have Apogee's standard stainless-steel connectors, you only need to send the sensor with the 30 cm section of cable and one-half of the connector. We have mating connectors at our factory that can be used for calibrating the sensor.*

3. Please write the RMA number on the outside of the shipping container.

4. Return the item with freight pre-paid and fully insured to our factory address shown below. We are not responsible for any costs associated with the transportation of products across international borders.

Apogee Instruments, Inc.
721 West 1800 North Logan, UT
84321, USA

5. Upon receipt, Apogee Instruments will determine the cause of failure. If the product is found to be defective in terms of operation to the published specifications due to a failure of product materials or craftsmanship, Apogee Instruments will repair or replace the items free of charge. If it is determined that your product is not covered under warranty, you will be informed and given an estimated repair/replacement cost.

PRODUCTS BEYOND THE WARRANTY PERIOD

For issues with sensors beyond the warranty period, please contact Apogee at techsupport@apogeeinstruments.com to discuss repair or replacement options.

OTHER TERMS

The available remedy of defects under this warranty is for the repair or replacement of the original product, and Apogee Instruments is not responsible for any direct, indirect, incidental, or consequential damages, including but not limited to loss of income, loss of revenue, loss of profit, loss of data, loss of wages, loss of time, loss of sales, accrual of debts or expenses, injury to personal property, or injury to any person or any other type of damage or loss.

This limited warranty and any disputes arising out of or in connection with this limited warranty ("Disputes") shall be governed by the laws of the State of Utah, USA, excluding conflicts of law principles and excluding the Convention for the International Sale of Goods. The courts located in the State of Utah, USA, shall have exclusive jurisdiction over any Disputes.

This limited warranty gives you specific legal rights, and you may also have other rights, which vary from state to state and jurisdiction to jurisdiction, and which shall not be affected by this limited warranty. This warranty extends only to you and cannot be transferred or assigned. If any provision of this limited warranty is unlawful, void or unenforceable, that provision shall be deemed severable and shall not affect any remaining provisions. In case of any inconsistency between the English and other versions of this limited warranty, the English version shall prevail.

This warranty cannot be changed, assumed, or amended by any other person or agreement

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