PRODUCTS: Silicon Pyranometer Specifications

Model PYR

The Pyranometer Sensor is calibrated to measure the shortwave radiation reaching the Earth's surface. The evaporation of water from soil and the transpiration of water from leaves are partly determined by the intensity of this shortwave radiation, which is measured in Joules m^{-2} s^{-1} or Watts m^{-2}.

NEW! 06.01.05

We are pleased to announce the addition of a Precision Pyranometer Sensor (Model PYR-P). Model PYR-P is held to tighter manufacturing specifications, has better cosine response, and is calibrated over a multiple day period to a heated and ventilated Kipp & Zonen model CM21 thermopile radiometer. Model PYR-P has improved accuracy over our standard Model PYR-S (formerly Model PYR).

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SPECIFICATION COMPARISON FOR MODEL PYR-P AND PYR-S

BUY NOW!

SPECIFICATION	Model PYR-P	Model PYR-S
PRICE	$169	$139
COSINE RESPONSE	± 4% at 75° ± 1% at 45°	± 10% at 75° ± 3% at 45°
DAILY TOTAL RADIATION		
ABSOLUTE ACCURACY	± 5%	± 8%
REPRODUCIBILITY	± 1%	± 2%
CLICK ON IMAGES FOR LARGER VIEW: NOTE: THE ONLY VISUAL DIFFERENCE BETWEEN MODELS PYR-P AND PYR-S IS A BAND OF YELLOW HEATSHRINK ON THE LEAD WIRE AT THE BASE OF THE SENSOR ON MODEL PYR-P.		

GENERAL SPECIFICATIONS FOR BOTH SENSORS

OUTPUT	0.200 mV / W m^{-2} Output in full sunlight: 220 mV (1,100 W m^{-2}) Output linear to: 320 mV (1,600 W m^{-2})
SENSITIVITY	5.00 W m^{-2} / mV
POWER REQUIREMENTS	None. Self-powered.
OPERATING ENVIRONMENT	-40 to 55 °C; 0 to 100% relative humidity. Designed for continuous outdoor use. Can be submerged underwater.
TEMPERATURE RESPONSE	<1 % from 5 to 40 °C
MATERIALS	Type II anodized aluminum with acrylic diffusion disk; the only visual difference between Model PYR-P and Model PYR-S is the precision model has yellow lead wire at the entry to the sensor (pictures available soon).

DIMENSIONS & MASS	**24 mm dia., 27.5 mm tall** **70 g (with 2 m lead wire)**
CABLE	**2 meters of shielded, twisted-pair wire with Santoprene casing,ending in pigtail leads:** **Red wire is positive / high** **Black wire is negative / low** **Bare / clear wire is shield (ground)** **Sensors can be built with additional cable for $1.95/meter ($0.63 / ft)**
WARRANTY	**1 year parts and labor**

ALSO AVAILABLE, AMPLIFIED PYRANOMETER SENSORS: These sensors have the same performance as listed above, but with an amplified signal. Choose precision or standard with a either 0 to 2.5 V or 0 to 5 V output.

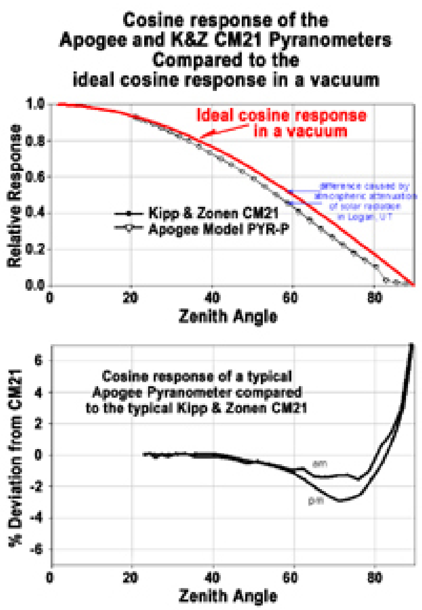
SPECIFICATION	**Model PYR-PA5**	**Model PYR-PA2.5**	**Model PYR-SA5**	**Model PYR-SA2.5**
PRICE	**$219**	**$219**	**$189**	**$189**
OUTPUT	**0 to 5 V**	**0 to 2.5 V**	**0 to 5 V**	**0 to 2.5 V**
POWER REQUIREMENTS	**5 VDC**	**5 VDC**	**5 VDC**	**5 VDC**

COSINE RESPONSE

The term cosine or Lambertian response is the decrease in radiation intensity on a flat surface as the angle of the surface decreases from perpendicular (normal or 0 degrees zenith angle). This is known as Lambert's Cosine Law and is expressed as: $E_\theta = E * \cos(\theta)$

The ideal cosine response is shown in red in the top graph at the right.

A radiation sensor that is "cosine corrected" is designed to accurately measure the amount of radiation coming from different angles. The output should decrease by the cosine of the incident angle irradiance source, although particulate matter and humidity in our atmosphere attenuate the light, particularly at low sun angles (see figure at right). Sensors with a good cosine response read accurately throughout the day as the sun angle changes from dawn to solar noon to dusk. Sensors with poor cosine response can be calibrated so that they will accurately measure daily total radiation when the sun angle is the same as the day of calibration, however, they will not be accurate at different times of the year. A sensor with good cosine correction will be accurate at all times of the year as the sun angle changes from summer to winter.

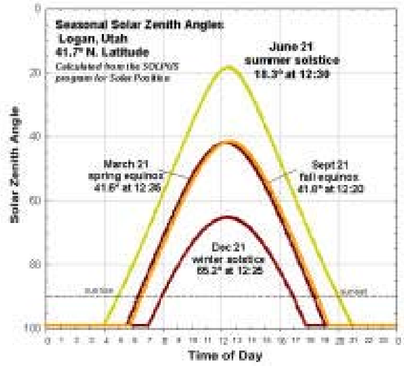


CLICK IMAGE ABOVE FOR LARGER VIEW OF GRAPH DETAILING THE IDEAL COSINE RESPONSE AND THE COSINE RESPONSE OF THE APOGEE PYRANOMETER AS COMPARED TO THE KIPP & ZONEN CM21.

All radiation sensors have some azimuth error, which shows up as the difference between the am and pm response. This error is typically smaller than the cosine error. To minimize azimuth error we calibrate Apogee sensors with the lead wire pointing north (in the Northern hemisphere) and we recommend mounting the sensor with the wire pointing north. Most of the azimuth error is thus corrected in the calibration.

The Figure on the right shows the magnitude of seasonal changes in sun angle in Logan Utah. Seasonal changes result in a 23.5^{o} variation in solar angle between the solstice and

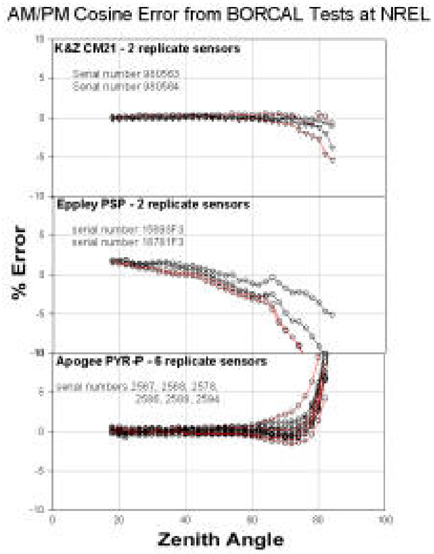
equinox and 47° between the winter and summer solstices. For example the zenith angle in Logan, Utah at solar noon varies from 18.3° on June 22 to just 65.2° on December 22. Remember that 0° is directly overhead.



CLICK IMAGE ABOVE FOR LARGER VIEW OF GRAPH SHOWING SEASONAL SOLAR ZENITH ANGLES FOR 41.7 NORTH LATITUDE (LOGAN, UTAH).

In a series of tests in the summer and fall of 2004 we refined the cosine response of the Apogee pyranometer. Broadband Outdoor Radiation Calibration (BORCAL) test results at the National Renewable Energy Laboratory (NREL) in Boulder, Colorado in June of 2005 confirmed that all six replicate Apogee sensors exceeded our specification for cosine response. Results of these tests are available from NREL. These tests have also shown that the CM21 has excellent cosine response. Tests at NREL show that the Eppley model PSP under corrects for low angle radiation. NREL normalizes all of the cosine error data to zero error at 45 degrees, which is the approximate average sun angle at most latitudes.

The castle design. A flat sensor surface (without cosine correction) reflects radiation at low angles and under-weights low angle radiation. A sensor with a raised white diffusion disk over-weights low angle radiation. The traditional approach to achieving a good cosine response is to build a sensor with a raised, white disk, and then add a raised wall around the perimeter to block low angle radiation (this is called the castle design). This is an effective design, but it traps water and dust, which block light and result in low readings. The Apogee sensor uses a domed top to repel water and dust. This makes the sensor self cleaning. Accurate cosine response is achieved by having just the right amount of curvature on the dome, as well as using an appropriately opaque diffuser.



CLICK IMAGE ABOVE FOR LARGER VIEW OF GRAPH OF DATA FROM BORCAL TESTS AT NREL OF THE APOGEE MODEL PYR-P, EPPLEY PSP, AND K&Z CM21 SENSORS.

LONG-TERM STABILITY and RECALIBRATION

CALIBRATION The pyranometer is calibrated to provide an output of exactly 0.2 mV per W m^{-2}. The output of all radiation sensors tends to decrease over time as the detector ages. Our measurements indicate that the average decrease of the sensor is less than 1 % per year.

RECALIBRATION OF PYRANOMETER SENSOR: $40
Apogee recommends that you send your sensors in every 3 years for recalibration. Please contact Apogee for an RMA. *Do not attempt recalibration without a radiation standard.*

OF SPECIAL NOTE: The biggest error in measuring shortwave radiation on an automated weather station is usually caused by occlusion of the lens of a sensor by dust or water residue. This error can be minimized by frequent cleaning of the dome of the sensor, but a more cost effective way to minimize this error is to connect two replicate sensors and measure both sensors simultaneously. If the sensors are providing similar values they have either both simultaneously changed, or they are clean and correct. A difference in the output of the sensors indicates that one of them has become compromised.

The sensor with the lower reading is probably dirty and needs to be cleaned. If there is an extra channel in your data acquisition system, adding a second replicate sensor is a good way to improve the long term accuracy of your measurements.

MAKING A MEASUREMENT

The biggest error is often caused by dirt on the lens of the sensor. The domed top is self-cleaning, but measurement accuracy will be improved if the lens is wiped with a clean, soft cloth at frequent intervals.

Small changes in the level of the sensor can also cause large errors. Make sure that the top of the domed sensor body is kept horizontal. To assist in this, we offer a Leveling Plate (Model LEV) for only $29.

The sensor should be mounted with the cable pointing toward the nearest magnetic pole. For example: In the Northern Hemisphere, point cable toward the North Pole. In the Southern Hemisphere, point cable toward the South Pole.

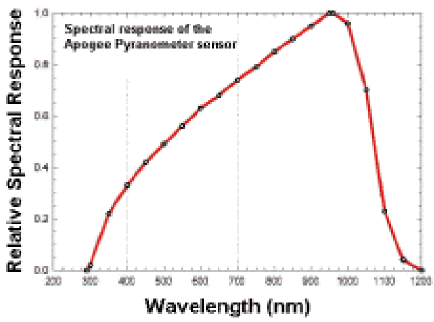
CLICK FOR LARGER IMAGE AND SCHEMATIC DRAWING

SPECTRAL RESPONSE

A thermopile pyranometer measures all of the energy between 280 and 2800 nm. However, about 90% of the sunlight energy is between 300 to 1100 nm so silicon pyranometers can be calibrated to estimate all of the shortwave energy from sunlight.

NOTE ON USE OF THE APOGEE SILICON PYRANOMETER

All silicon Pyranometers sub-sample the shortwave radiation spectrum (from 350-1000 nm), and are calibrated to predict all of the solar radiation (from 280 to 2800 nm). For this reason, they should only be used to measure unobstructed solar radiation. They should not be used to measure electric lights, under canopies of vegetation or to measure reflected radiation.



CLICK ON IMAGE AT RIGHT FOR LARGER VIEW

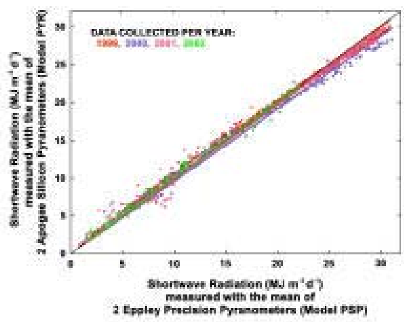
TEMPERATURE RESPONSE

Increasing temperature decreases the output of most silicon photodiodes. Our measurements indicate that temperature errors are less than 1% between 5°C and 40°C. The temperature error is insignificant for most applications.

LONG-TERM TEST RESULTS

We began a study in August 1997 to measure long term stability and sensor drift Quantum Sensors, Pyranometers and UV Sensors.

The graph at the right is some of the data comparing 2 of the Apogee Silicon Pyranometers to the mean of 2 Eppley precision pyranometers (Model PSP).



CLICK ON IMAGE AT RIGHT FOR LARGER VIEW

MORE INFORMATION ON SHORTWAVE RADIATION

The American Society of Agronomy recently published a comprehensive reference book on environmental instrumentation. The book, entitled "Micrometeorology in Agricultural Systems," is available from the Agronomy Society (www.agronomy.org).

The table of contents and ordering information are available at:
https://secure.societystore.org/more.php?id=125.

This book includes a chapter on the principles and challenges of measuring shortwave radiation written by Steve Klassen and Bruce Bugbee.