APOGEE INSTRUMENTS
PYRANOMETER IMPROVEMENTS

September 27, 2013

Apogee is dedicated to continuous improvement of sensor designs and manufacturing processes. Here we describe the upgrades to our silicon-cell pyranometer line since 2009.

IMPROVEMENTS TIMELINE

Date	Change	Result
April 2009	Changed adhesive from RTV silicone to epoxy.	Eliminated diffuser detachment in hot, humid climates.
Jan. 2010	Upgraded to UV-cured silicone adhesive.	Improved stability of optical path.
Dec. 2010	Moved calibration circuitry from sensor head to tailboard.	Increased calibration accuracy and decreased lead time.
March 2011	Optimized dimensions of photodiode cavity.	Improved cosine response and sensor consistency.
Oct. 2011	Moved calibration circuitry from tailboard to sensor head.	Retained calibration accuracy while allowing cleaner design.
Dec. 2011	Optimized internal dimensions to allow for thicker layer of adhesive.	Further improvement of stability and uniformity among sensors.
Aug. 2012	Changed to a less thermally expansive potting compound.	Eliminated expansion of potting compound in high-temperature field conditions.
July 2013	Switched to lead-free solder.	RoHS compliance.

TESTING METHODOLOGY AND DATA SUMMARY

To quantify the long-term stability of products, Apogee has conducted "accelerated-aging" tests that exceed the harshest conditions instruments will encounter in the field. These tests include extended temperature and humidity cycling. Sensors have also been subjected to extended roof-top exposure. Pyranometers from other manufacturers are included in these tests.

We are pleased to report that Apogee pyranometers equal or exceed the other silicon-cell pyranometers on the market for long-term stability, cosine response, and year-around accuracy (see test data on page 2). Based on sensor performance results, we are also pleased to announce that effective immediately Apogee offers a four-year warranty on all models of pyranometers.

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TEST DATA

Figure 1: Percent change in pyranometer accuracy after 400 days in accelerated aging chamber. Sensors were cycled from -20 C to 60 C twice daily. Humidity levels were cycled between 20 and 80 % relative humidity.

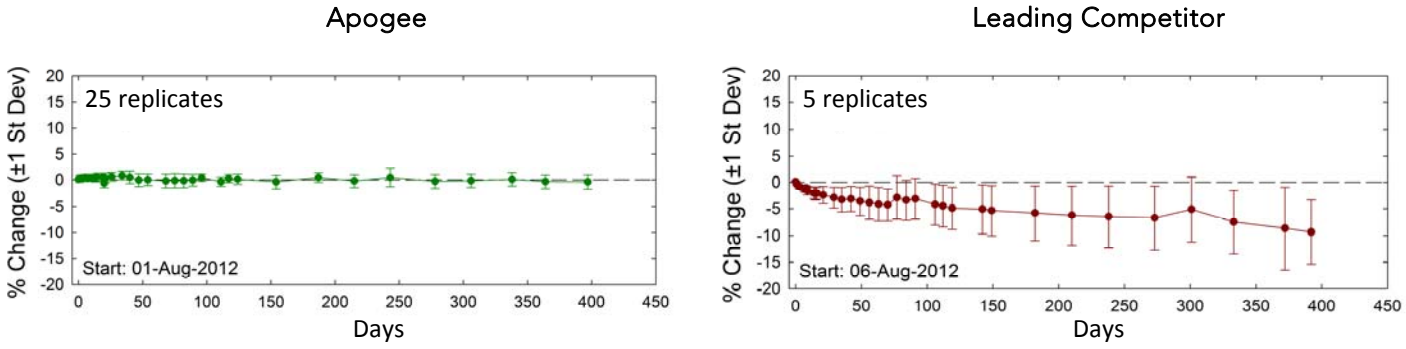

Figure 2: Cosine response measurements from the National Renewable Energy Laboratory (NREL).

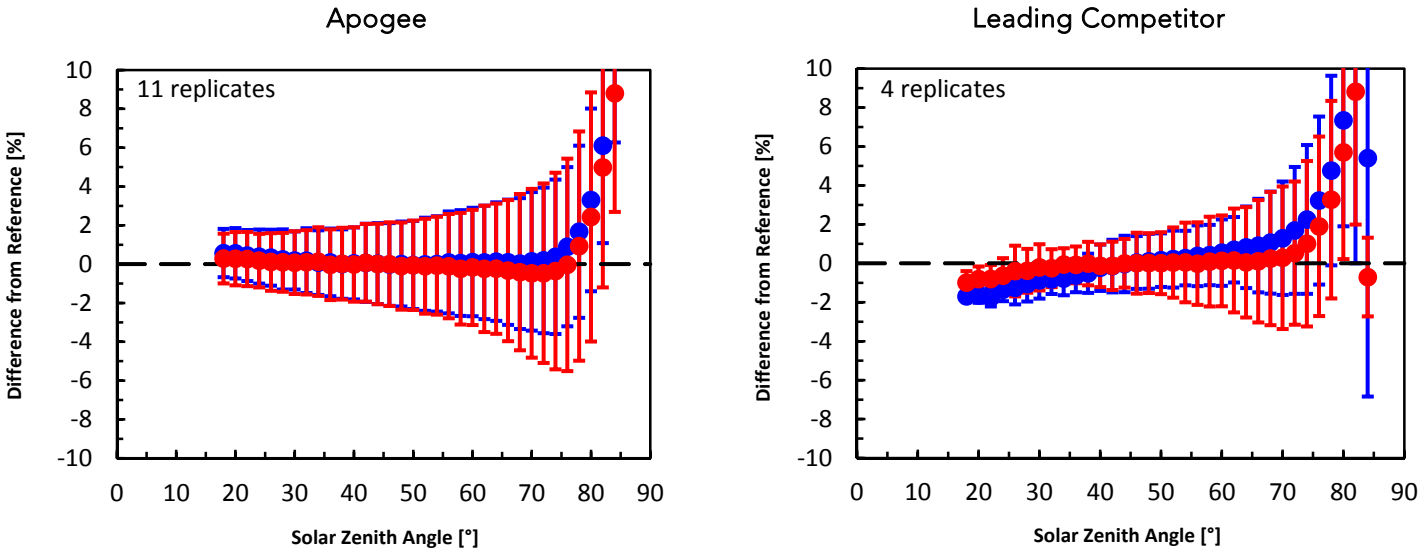

Table 1: Root mean squared difference (RMSD) of silicon-cell pyranometer measurements relative to mean of four replicate reference blackbody pyranometers (ISO-classified). RMSD is also shown as a percentage of the mean shortwave radiation.

	Apogee	Leading Competitor
RMSD [W m^{-2}]	10.7	11.0
RMSD / Mean [%]	1.50	1.54

Data were collected from January through September 2013 (266 days), and were filtered for conditions of dry surface, clear sky (ratio of actual to predicted clear sky solar radiation between 0.9 and 1.1), and solar zenith angle less than 80°. With data filter applied, 5118 data points (fifteen minute average) were included in calculation of RMSD and RMSD / Mean. RMSD is mean value calculated from individual RMSD values from 32 replicate Apogee pyranometers and three replicate pyranometers from the leading competitor. *A fourth pyranometer from the leading competitor was included in the test, but data were erratic and it was not clear whether the sensor or a bad connection was the problem, thus it was not included in the calculation of the RMSD shown in the table.*