MS-57 High precision pyrheliometer "Measuring faster"

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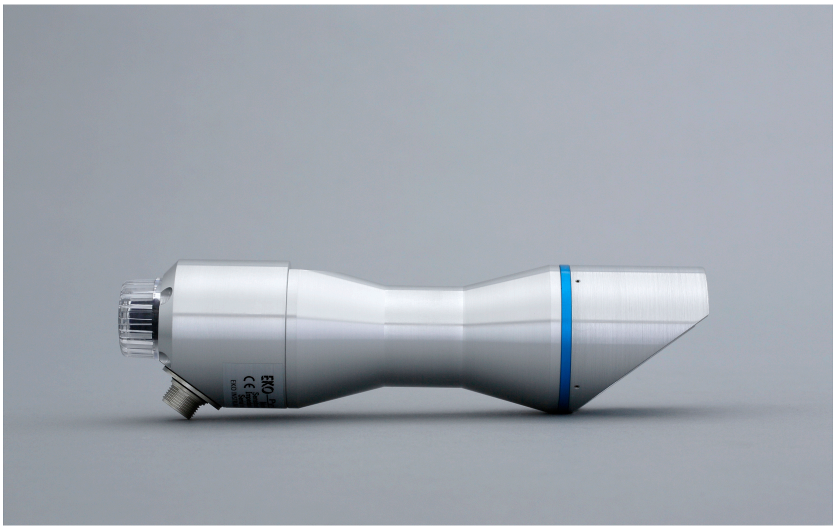
The new MS-57 pyrheliometer was inspired by the latest development of the MS-80 pyranometer enabling a breakthrough in unprecedented low thermal offset behaviour and fast thermopile response. The MS-57 real time performance makes measurements more realistic.

The MS-57 is brand new on the inside, but little change in appearance. The performance characteristics were optimized and matched with the fast response MS-80 pyranometer to enable simultaneous measurements. This way sub-second temporal changes can be accurately measured in the solar irradiance. EKO sub-second thermopile sensors are analog devices, and naturally respond to irradiance changes. Contrary to digitally enhanced sensors, which may show overshoot or undershoot. The all-weather MS-57 is sensitive to solar irradiance in the spectral range 200 – 4000nm and works under the most extreme conditions in a temperature range from -40°C to 80°C. The pyrheliometer has a user controlled heated front window to avoid condensation and ice affecting the measurements.




MS-57 Pyrheliometer

Measuring faster

EKO's radiometers, when combined with the appropriate data acquisition system can sample much faster than previous versions. Faster sample rates allow the sensor to 'catch' more accurately the peak irradiance values during variable atmospheric conditions. Even on clear sky days the Solar irradiance seem to be constant on a minute scale. Due to atmospheric turbidity the irradiance can easily fluctuate by a few W/m^2. To detect sub-second changes, it is important to match the sampling rate of the data acquisition system with the sensor response time. As rule of thumb, the sampling time should be below the response time (t = 63%) of the sensor. Hence data reduction can be applied to store only minute values.

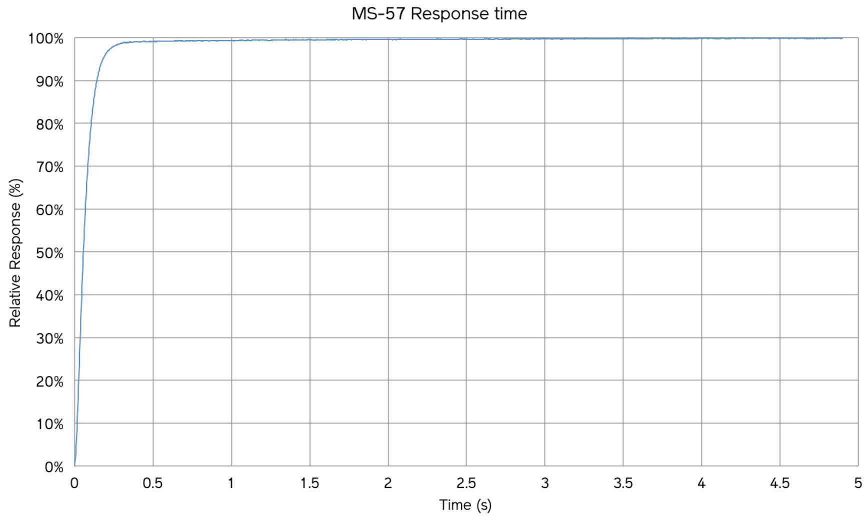
"Measuring faster", requires faster sampling of the data. When comparing sub-second sensors with traditional slower response sensors, obviously the data acquisition system should be matched with the fastest sensor in the system. Under sampling conditions lead to substantial mismatch and anomalies when sensors with different time constant are compared with each other. Commonly when the data acquisition sampling time is set to 1s, it gives the impression that the fast sensor is instable. In contrary, it is the slower sensor smoothing the irregular pattern of the actual irradiance.

Test results

EKO sensors were extensively tested indoors and outdoors. The sensors characteristics are based on the typical values as measured by multiple sensors.

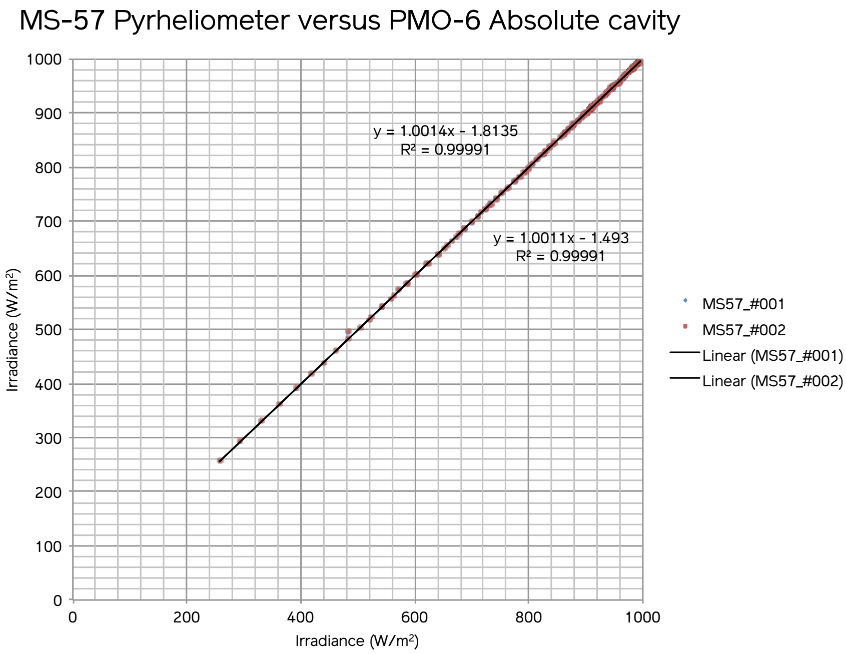
Response time

The MS-57 has an analog thermopile providing a response time, which is only a fraction of second (< 0.5s / 99%). A fast detector is beneficial to stay perfectly in sync with rapid atmospheric changes. Data can be sampled at a higher frequency to minimize the measurement uncertainty for one minute or longer averaged values.



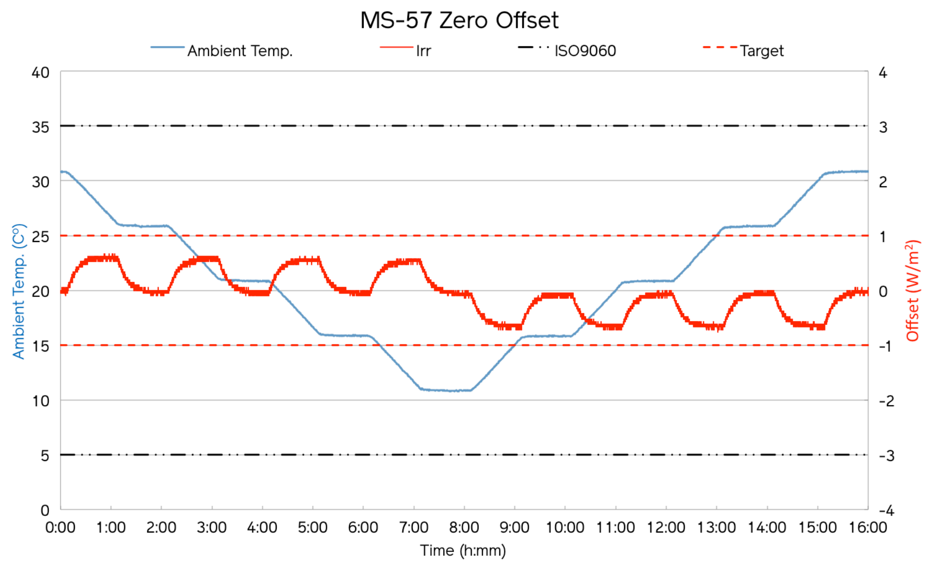
Non-linearity

To initiate further improvement of MS-57 non-linearity a reliable test method was developed to measure the detector non-linearity indoors and outdoors. The characteristics were validated by cross comparison against the PMO-6 absolute cavity pyrheliometer outdoors. Measurements demonstrated the non-linearity < 0.1% in the range 100 – 1000W/m^2.



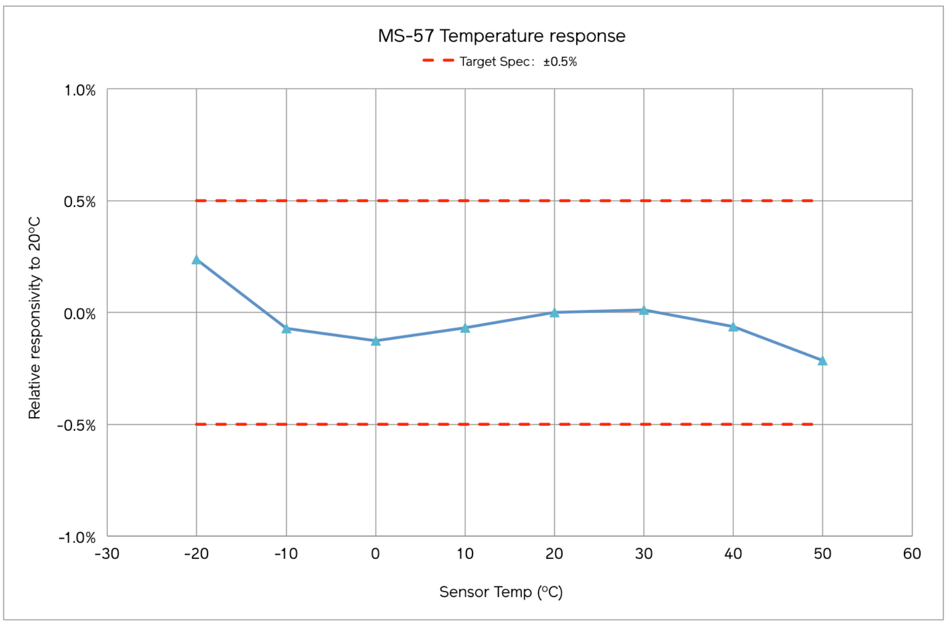
Zero offsets

Offsets are a consequence of thermal differences between the optics and detector, which are variable and influenced by conditional radiative and convective factors (Irradiance / Net-IR / Temperature). Offsets are negligible due to the isolated detector construction applied. Hence MS-57 give a stable output under variable temperature conditions.



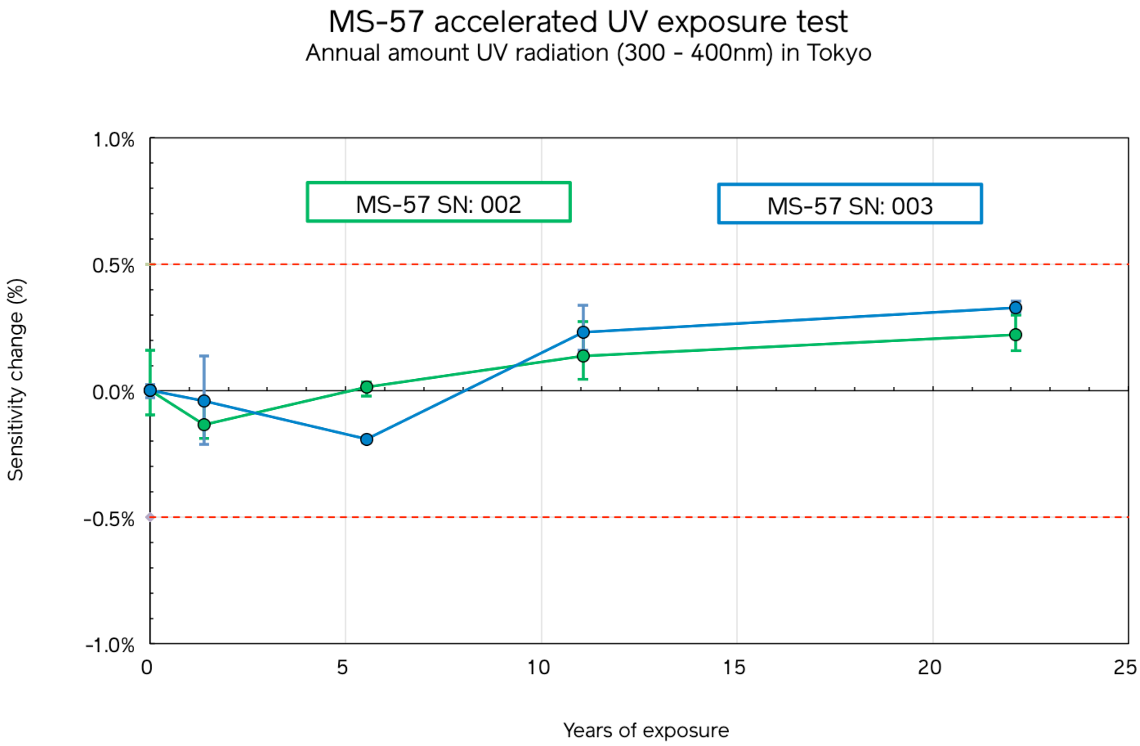
Temperature dependency

Due to the enhanced embedded analog temperature compensation electronics, the detector has a very low temperature coefficient. The MS-57 gives a linear output as a function of the irradiance in a wide temperature range, without the need for data correction. At the EKO manufacturing facility, the detector temperature dependency is measured and adjusted to meet the tight temperature specifications within the range -20°C to 50°C and beyond.



Long-term stability

A third-party test lab performed an extensive UV stability test (JIS B7751 "Light-exposure and light-and-water-exposure apparatus) and thermal cycle test to simulate and validate the sensor performance over a long period of field operation. Results do not reveal any degradation of the detector responsivity over time larger than 0.5% taken into account the uncertainty of the measurement method.
Compared to all other pyrheliometers in the market the MS-57 has improved long-term stability properties. Therefore, the recommended period of recalibration can be extended to 5 years, which is typically 2 years for other sensor models in the market. The long-term stability of the sensor responsivity is less than 0.5% in a period of 5 years, which makes it unique. Based on the hermetically sealed construction and high quality sensor components also the standard warranty period is 5 years. All features that in combination make up the most cost effective pyrheliometer to date.



Lowest measurement uncertainty

Measurement performance of a pyrheliometer can only be determined when compared against an absolute cavity pyrheliometer, a device that represents the lowest measurement uncertainty against the World Radiometric Reference (WRR). In practice when routine pyrheliometers are properly calibrated, an instrument can achieve a ± 1% measurement uncertainty of the measured DNI against the absolute cavity radiometer. With MS-57 lower measurement uncertainty values can be achieved getting in close range with the absolute cavity.

A brief look at the MS-57 specification list gives an impression of the many parameters that affect the radiation measurements. Fortunately, all these individual error sources, which have a small magnitude, will rarely affect the measurement at the same time. However, it is very difficult to calculate the combined measurement uncertainty because it is nearly impossible to isolate the individual measurement conditions to determine the corresponding errors. This illustrates the difficulty and complexity of the measurement uncertainty calculation. However, when considering the pyranometer specifications, an assessment can be made for the measurement uncertainty of ISO 9060 first class pyrheliometer. For the analysis, several assumptions were made with respect to the individual specifications taking into account the measurement and calibration uncertainty and conditions. The specifications for the ISO 9060 pyrheliometer classes are based on the specifications for a common brand model in the market. Generally, the sensor specifications are better than the limiting specification defined by ISO 9060.

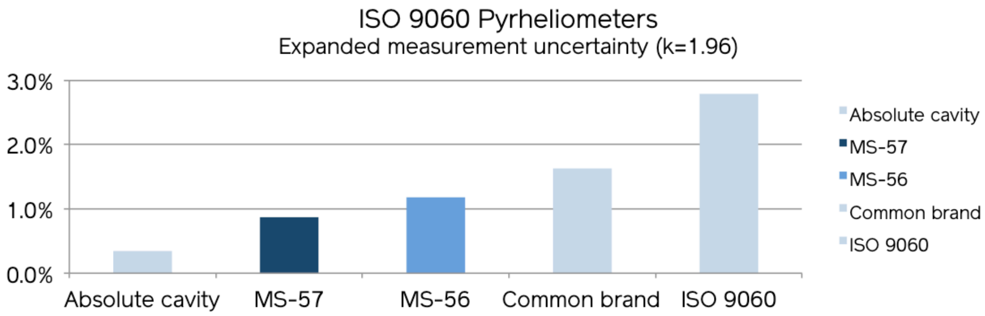


Table 1: Expanded uncertainty first class pyrheliometers

	Absolute cavity	MS-57	MS-56	Common brand	ISO 9060
Calibration accuracy* (%)	0.3	0.5	0.7	1.0	1.0
Zero offset A (W/m2)	0	0.0	0.0	0.0	0.0
Zero offset B (W/m2)	0	1.0	1.0	1.0	3.0
Non-Stability (%)	0.1	0.2	0.5	0.5	1.0
Non-linearity (%)	0.1	0.2	0.5	0.2	0.5
Spectral selectivity** (%)	0	0.2	0.2	0.2	0.2
Temperature response*** (%)	0	0.5	0.5	1.0	2.0
Tilt response (%)	0.1	0.2	0.2	0.2	0.5
Expanded uncertainty (k=1.96)	0.34%	0.9%	1.2%	1.6%	2.8%

*Calibration uncertainty commonly specified in the market (EKO Calibration uncertainty = 0.7% K=1.96) / **Effect of sensor spectral selectivity / ***Calibration reference temperature 20ºC (-20ºC to 50ºC) / (Response time not accounted for)

The expanded measurement uncertainty associated with the ISO 9060 pyrheliometer class is calculated as the square root of the sum of the squares of the individual uncertainties and could be considered the worst-case scenario.

Pyrheliometer Calibration at EKO

Contrary to what most manufacturers do, all EKO pyrheliometers are calibrated outdoors. Pyrheliometers are less susceptible to offsets, temperature and angular effects, therefore consistent calibrations can be performed outdoors. The EKO calibration laboratory is ISO 17025 accredited to perform ISO 9059 pyrheliometer calibrations.

EKO Instruments Co. Ltd. calibration laboratory is accredited and certified by PJLA (Ref: **#74158**) to perform pyranometer and pyrheliometer calibrations in accordance with the requirements of ISO/IEC17025, which are relevant to calibration and testing.

EKO offer a unique manufacturer calibration service for pyranometers and pyrheliometers in-house. Based on the applied calibration methods EKO provides the best quality Solar sensor calibrations compliant to the international standards defined by ISO/IEC17025 / 9847 (Indoor method) and 9059 (Outdoor method), as defined by the scope of calibrations. The calibration and measurement capability expressed as an uncertainty is 0.63% for the calibration transfer.

ISO/IEC17025 provides a globally accepted basis for laboratory accreditation that specifies the management and technical requirements.

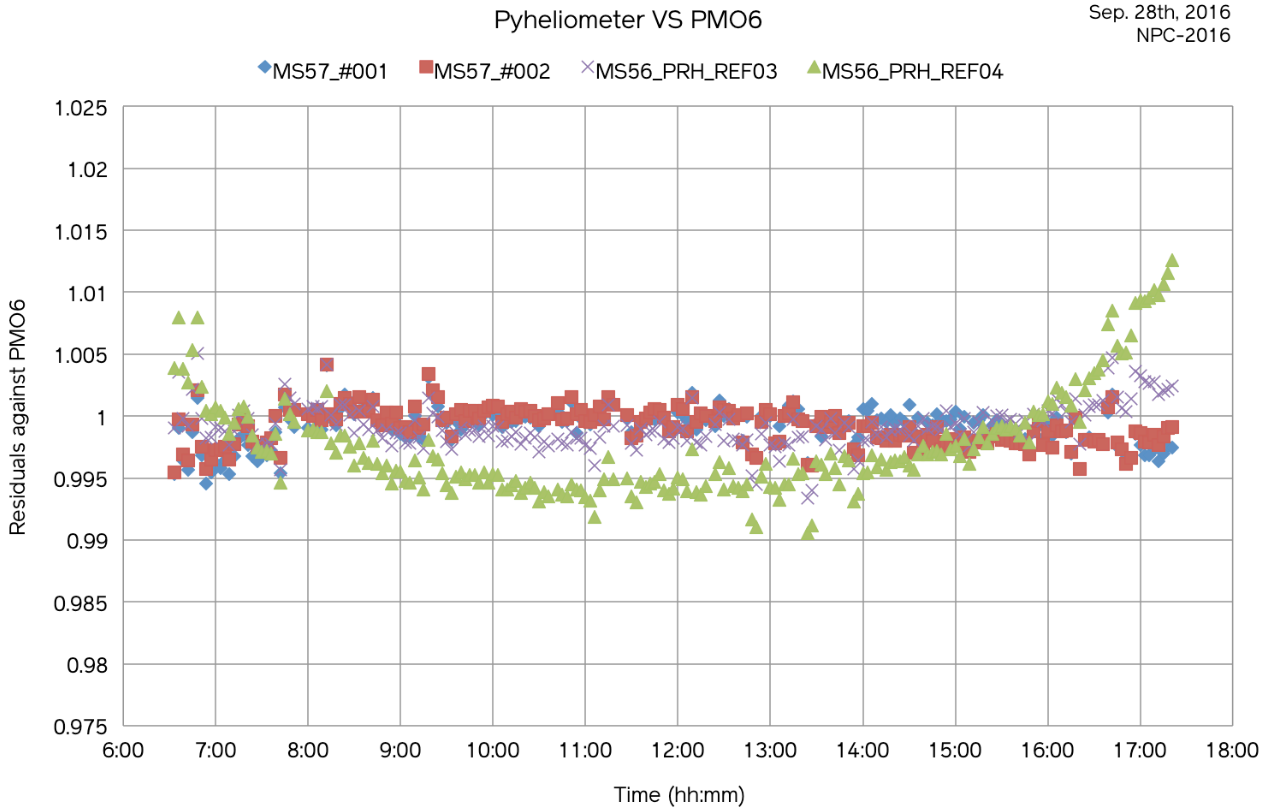
With calibrations performed at the EKO Instruments laboratory we enable our customers to:

- Clearly identify the applied calibration methods and precision
- Be traceable to the World Radiometric Reference (WRR) through defined industrial standards:
    - ISO9846 Calibration of a pyranometer using a pyrheliometer -
    - ISO9847 Calibration of field pyranometer by comparison to a reference pyranometer -
    - ISO9059 Calibration of field pyrheliometers by comparison to a reference pyrheliometer - Obtain repeatable and reliable calibration test results through consistent operations yearly examined independently to assure strict compliance to the requirements.

Our clients will obtain the highest level of confidence when purchasing an ISO/IEC17025 calibrated sensor. EKO's Accredited lab is regularly re-examined to ensure that they maintain their standards of technical as well as managerial expertise.

Outstanding performance

During the NPC 2016 event at NREL the MS-57 was extensively tested against EKO reference pyrheliometer PMO-6 and the other reference sensors. The NPC is an annual event to compare and calibrate pyrheliometers against the reference sensors maintained at NREL. In the graph below the residuals are plotted and show excellent agreement with the PMO 6 maintained as the reference at EKO. The MS-57 measurement uncertainty %U95 stated in the NPC report was respectively 0.41 to 0.43 compared to 0.54 to 0.65 for the MS-56.



Sensor characteristics

	MS-56	MS-57
ISO 9060 Classification	First Class	First Class
Detector	Thermopile	Thermopile
Wavelength Range	200 to 4000 nm	200 to 4000 nm
Response time 95 %	< 1 s	**< 0.2 s**
Zero offset A / Thermal Radiation (200W/m²)	0 W/m²	0 W/m²
Zero offset B / Temperature Change (5K/hr)	< +/- 1 W/m²	< +/- 1 W/m²
Non-Stability (change/yr)	< 0.5 %	< 0.5 % / **5 yrs**
Non-Linearity (100 - 1000W/m²)	< 0.5 %	**< 0.2 %**
Directional Response	N/A	N/A
Spectral Selectivity / (0.35 to 1.5μm)	< 1 %	< 1 %
Temperature Response (-20°C to 50°C)	< 0.5 %	< 0.5 %
Tilt Response (0-90° | 1000W/m²)	< +/- 0.2 %	< +/- 0.2 %
Irradiance Range (W/m²)	0 to 2000	0 to 4000
Nominal Sensitivity (μV/W/m²)	6 - 10	7 - 8
Nominal Impedance	< 5 kΩ	**< 15 kΩ**
Operating Temperature	- 40 to 80°C	- 40 to 80°C
Heated Window / Power @ 12VDC	Yes / 0.3W	Yes / 0.3W
Temperature Sensor	YSI 44031	YSI 44031
Calibration Accreditation / Method	ISO 17025 / 9059	ISO 17025 / 9059

MS-57 market value

In terms of measurement accuracy, the new MS-57 pyrheliometer closes the gap between the ISO 9060 first class pyrheliometers and primary standard sensors (absolute cavity radiometers). It is an evolution of the latest isolated sensor technology and expertise developed by EKO.

Measuring faster makes measurements more indicative of the actual changing environment. This is paramount for short-term trend detection applications. For decades, it was impossible to perform broadband Solar irradiance measurement on a sub-second level. The detector technology was the limiting factor although the data acquisition systems basically had no limitation sampling at a high frequency. Now all solar components (DNI, GHI, DHI) can be measured at a sub second scale with the MS-57 Pyrheliometer and MS-80 Secondary standard pyranometer.

Pyrheliometers are commonly used in most demanding research projects where accuracy matters. The MS-57 represents the lowest measurement uncertainty values in its range.

The MS-57 has analog temperature compensation instead of requiring the user to apply a post processing temperature correction method. The detector temperature can be monitored but there is no need to correct any data. The compensation is intrinsically made to the detector analog output. The MS-57 pyrheliometers are manufactured in a consistent way followed by strict quality inspection and performance evaluation. For each sensor, the temperature dependency is measured and validated through a measurement report that comes with the sensor.

The MS-57 has a standard full 5° (degrees) opening angle and 1° slope angle as defined by ISO Pyrheliometers Standards and greatly performs when used in combination with the EKO STR-21(G) or STR-22(G) Sun Tracker. The integrated low power window heater prevents dew deposition or frost on the outside window and makes it suitable to be used in harsh environments. Each MS-57 is calibrated and tested at EKO against EKO's reference sensors which are fully traceable to the WRR (World Radiometric Reference) maintained at the PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center) in Davos, Switzerland.