# PYRANOMETER SITE CONFIDENCE CHECK

We are often asked if it is possible to make a confidence check of the measurements made by a site pyranometer at a PV power plant. The answer is yes, but you need to be aware of the limitations and that it is not a substitute for a 'real' calibration. Please see the following explanation.

## Pyranometer Calibration Standards

Various international standards related to solar energy require that pyranometers for the measurement of Global Horizontal Irradiance (GHI) or Global Tilted Irradiance (GTI) are calibrated in accordance with ISO 9847:1992 or ISO 9846:1993 and this includes IEC 61724-1, which specifies calibration every year for Class A monitoring and every 2 years for Class B monitoring

In the absence of such a standard being used for equipment operation and maintenance (O&M) Kipp & Zonen recommends recalibration of field pyranometers every two years.

ISO 9846 is for outdoor calibration using a reference pyrheliometer that measures Direct Normal Irradiance (DNI) and a shaded reference pyranometer that measures Diffuse Horizontal Irradiance (DHI). From these values, and the solar zenith angle at the time of measurement, the GHI is calculated for comparison to the field (test) pyranometer measurements.

ISO 9847 is titled 'Solar energy - Calibration of field pyranometers by comparison to a reference pyranometer' and this covers both outdoor calibration and several methods for calibration indoors (one of which, under type IIc, is the 'Kipp & Zonen device and procedure').

Reference instruments should have a suitable calibration that is not more than 12 months old at the time of use and that is traceable to the World Radiometric Reference (WRR) in Davos, Switzerland.

The World Meteorological Organisation (WMO) states that a field pyranometer must be either calibrated to a standard on site, or exchanged for one that is newly calibrated, every year.

## Calibration or Check

An outdoor pyranometer calibration to either 9846 or 9847 requires 2-3 days of clear skies (much longer if partially cloudy). There are strict requirements on mounting the field and reference units on a 'common calibration table', cleaning during the period, data logging, data processing and data validation. To comply with the standards the certificate produced must have all the same traceability, uncertainty, and other information as on a pyranometer calibration certificate from Kipp & Zonen.

There is no description in any ISO standard related to solar energy of a field 'check' or 'verification', but the WMO does allow for (and recommend) 'Routine checks on calibration factors' by comparison with a reference pyranometer between scheduled calibrations.

This type of check can be carried out at a solar plant by 'qualified' O&M personnel or a third party.

## How to Perform a Site Confidence Check

This is similar to an outdoor calibration to ISO 9847; but with simpler mountings, a shorter measurement period, a lot less data processing and no detailed certificate.

### *When to make the comparison?*

Typically, two or three hours each side of local solar noon (not 12:00 clock time) on a day when the sun is clear; some scattered clouds that are away from the sun won't make a significant difference. Ideally, this would be done in the summer when the sun's path is highest in the sky.

### *Prepare the field pyranometer*

First the field pyranometer must be inspected and any damage noted (preferably photographs taken) and corrected. It must be cleaned, desiccant changed (if applicable), cabling and alignment checked and the weather conditions noted.

### *Reference Pyranometer*

You need a clean, well-maintained reference pyranometer with a recent and reliable traceable calibration and it should be at least as good in performance as the field pyranometer (ideally, a CMP22 or SMP22 to minimise uncertainty). If the reference pyranometer is kept warm and dry and in the dark when not in use for the confidence check, the sensitivity will not change significantly.

CMP22 and SMP22 have a calibration uncertainty of about ± 1% at the 95% confidence level (k=2). Most pyranometer manufacturers calibrate indoors at a temperature around +20°C and with the 'sun' (calibration lamp) at 0° solar zenith angle (directly overhead) and at about 500 W/m$^2$ irradiance.

When measuring outdoors, the conditions are different and are changing during the day, so additional measurement errors/uncertainties are introduced. SMP22 has excellent internal temperature correction < 0.3% (-40 °C to +70 °C), low thermal offsets, and good directional response and non-linearity. In a confidence check a SMP22 should measure within ± 1.1% of the 'true' value.

### *Mounting*

The best comparison result will be obtained by mounting both reference and field pyranometers horizontally and close to each other and with a clear view of the sky, to measure global horizontal irradiance (GHI). However, you can mount the reference pyranometer accurately tilted at the same angles as a Plane Of Array (POA) field pyranometer and close to it. Ensuring that they have the same view of the ground and arrays in front of them is the key point.

There should be no shadows on the pyranometer domes during the comparison period. If this cannot be avoided because of site structures, the data at this time should be excluded from the analysis.

### *Data Loggers*

Both pyranometers should be connected to the same high quality portable data logger; because there could be issues with the site cabling, power, or data logger / SCADA systems.

LOGBOX SE

This data logger is compact, weatherproof, has multiple inputs and the internal batteries can easily run SMP pyranometers for the comparison period (CMP models do not require power).

Usually, you sample every second and log 1 minute averages with the maximum and minimum and standard deviation. This allows the downloaded data to be screened for outliers before comparing the measurements in a spreadsheet.

There is no display on the LOGBOX SE but it can be configured on site, live data viewed and logged files downloaded via USB using a laptop computer and the Windows™ setup software.

METEON 2.0

This data logger is not weatherproof, but you only make the comparison in fine conditions so this is not a problem. The field pyranometer is often a CMP model and METEON 2.0 only has one analogue input, so the reference needs to be a SMP model. It can run smart pyranometers from the internal batteries. It does have a display so that live data can be seen. It has similar features to the LOGBOX SE with Windows™ software and USB communication to a laptop, but it does not calculate standard deviation.


However, METEON 2.0 has a unique comparison mode that does most of the work for you. It sums the total irradiance during the logging period from each pyranometer and a report is generated in the logger that shows the difference between these two totals as a percentage. It cannot screen the data for outliers, so make sure that nothing affects the readings during the measurement period; such as shadows from site structures.

METEON 2.0 is supplied in a rugged carrying case that also offers room for a reference pyranometer and a 10 m cable, making a convenient portable ‘reference’ system.

### *After the Logging Period*

Reconnect the field pyranometer to the plant cable and check the data against the reference pyranometer/logger to see if there is a problem with the site systems. Depending upon the site logging interval this might need to be for up to 30 minutes.

### *Site Visit Report*

Analyse the data and make a report that includes all the relevant information; inspection details, work carried out, weather conditions, equipment used, and the difference between the total irradiances measured by the reference and field pyranometers.

The important issue is whether this difference is within the expected uncertainty. If not, it can be recommended that the field pyranometer should be recalibrated or exchanged and not wait until the next scheduled date.

## What is the Expected Comparison Uncertainty?

The expected likely measurement difference between the irradiance totals depends upon the models of reference and field pyranometers, the environmental conditions and the time since the last calibration.

Below is the most likely scenario for solar energy applications.

### *Field Pyranometer*

The most commonly specified pyranometers in solar energy applications comply with the requirements of ISO 9060:1990 Secondary Standard or the updated ISO 9060:2018 Spectrally Flat Class A. Typically, it is our passive CMP10 or CMP11 models or the Smart SMP10 and SMP11 equivalents. These all have a calibration uncertainty of about ± 1.4%.

However, they are more affected by changing field conditions than the SMP22 mentioned before. If the temperature during the Confidence Check is +20°C it is the same as at calibration; but if the pyranometer is at +40°C there is an additional error of up to ± 1%. However, under most conditions we expect a freshly calibrated or new C/SMP 10/11 to measure within ± 2% of the 'true' value.

There is a possible ageing effect during use, up to a maximum of ± 0.5% per year for these models.

### *Comparison Data*

If the reference pyranometer is a SMP22, maintained as previously described, we can be pretty sure that the measured total of irradiance is within ± 1.1% of the 'true' value. If the field C/SMP 10/11 was calibrated one year ago, it should be within ± 2.5%

In principle, the reference could be reading 1.1% high and the field pyranometer 2.5% low (or the other way around). So, the difference could be up to ± 3.6% and because the uncertainties are all at the 95% confidence level, in 5% of cases the difference could be greater. However, this is unlikely and probably they will be within ± 2%.

## What to do Next?

Site O&M circumstances and QA/QC requirements vary. However, it could be recommended (for the scenario described above) that, if the difference is more than ± 2.5% after a one year interval from the last calibration, the field pyranometer should be recalibrated.

If the difference is significantly larger, it is possible that the field pyranometer has been damaged in some way and it should be investigated, repaired and recalibrated. Issues could be damage as a result of dropping it (or some other impact), lightning or other electrical damage; or a failure to inspect and change external desiccant, causing it to become damp internally at some time.