KIPP & ZONEN
SINCE 1830

CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	017922010785
PYRANOMETER MODEL	CM 21
SERIAL NUMBER	010785
SENSITIVITY	10.89 µV/W/m² at normal incidence on horizontal pyranometer
IMPEDANCE	39 Ω
REFERENCE PYRANOMETER	Kipp & Zonen CMP 21 sn 070114 active from 01 August 2018
CALIBRATION DATE	04 October 2018
CLASSIFICATION	ISO 9060, Secondary Standard

Calibration procedure

The indoor calibration procedure is based on a side-by-side comparison with a reference pyranometer under an artificial sun fed by an AC voltage stabiliser. It embodies a 150 W Metal-Halide high-pressure gas discharge lamp. Behind the lamp is a reflector with a diameter of 16.2 cm. The reflector is 1 m above the pyranometers producing a vertical beam. The reference and test pyranometers are mounted horizontally on a table, which can rotate. The irradiance at the pyranometers is approximately 500 W/m². During the calibration procedure the reference and test pyranometer are interchanged to correct for any non-homogeneity of the beam. Temperature of calibration: 22±2 °C.

Hierarchy of traceability

The reference pyranometer was compared with the sun and sky radiation as source under clear sky conditions using the "alternating sun-and-shade method" ISO 9846 paragraph 5. The measurements were performed in Tabernas, Spain (latitude: 37.094°, longitude: -2.3547°, altitude: 503m above sea level). Dates of measurements: 8, 10-12 June 2018.
The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 769 to 1182 with a mean of 1031 W/m² and tilted diffuse radiation intensities from 99 to 191 with a mean of 132 W/m². The ambient temperature ranged from +22.8 to +29.7 with a mean of +27.3 °C.
The direct radiation on the reference pyranometer as obtained with the alternating-sun-shade method was compared to the DNI measured by the absolute cavity pyrheliometer PMO6 SN 103. The PMO6 is calibrated against the World Standard Group (WSG), maintained at the WRC Davos every International Pyrheliometer Comparison (IPC). The PMO6 participates every IPC since 2005 and it participates in the yearly NPC hosted by NREL in Golden, Colorado to verify its stability. WRR factor of PMO6: 0.99789 (from the last IPC, IPC-2015).

This calibration proved that the reference pyranometer has been stable and that the original sensitivity 8.37 ± 0.11 µV/W/m² is valid and will be applied (see PMOD calibration details). Observed sensitivity differences between the consecutive years are well within the calibration uncertainty.

PMOD calibration details: The reference pyranometer was compared with the sun and sky radiation as source under mainly clear sky conditions using the "continuous sun-and-shade method". The pyranometer was installed horizontally. During the comparisons, the global radiation ranged from 638 to 1195 with a mean of 874 W/m². The solar zenith angle varied from 23.5 to 49.8 with a mean of 32.9 degrees. The ambient temperature ranged from +12.6 to +26.2 with a mean of +23.7 °C. The sensitivity calculation is based on 435 individual measurements. The readings of the WSG are referred to the World Radiometric Reference (WRR). The estimated uncertainty of the WRR relative to SI is ±0.3%. The obtained sensitivity value and its expanded uncertainty (95% level of confidence) are valid for similar conditions and are:8.37 ± 0.11 µV/W/m². The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1558m above sea level). Dates of measurements: 24, 30 June 1, 2 July 2015.
Global radiation data were calculated from the direct solar radiation as measured with the absolute cavity pyrheliometer PMO2 (member of the WSG, WRR-Factor: 0.998623, based on the last IPC-2010) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM22 SN 020059 (ventilated with heated air).

Justification of total instrument calibration uncertainty

The combined uncertainty of the result of the calibration is the positive "root sum square" of two uncertainties.
1. The expanded uncertainty due to random effects and instrumental errors during the calibration of the reference CMP 21 is ± 0.11/8.37 = ± 1.31%. (See traceability text).
2. Based on experience, the expanded uncertainty of the transfer procedure (calibration by comparison) is estimated to be ±0.5%.
The estimated combined expanded uncertainty is the positive "root sum square" of these two uncertainties: $\sqrt{(1.31^2 + 0.5^2)} = \pm 1.41\%$.

Notice

The calibration certificate supplied with the instrument is valid at the date of first use. Even though the calibration certificate is dated relative to manufacture, or recalibration, the instrument does not undergo any sensitivity changes when kept in the original packing. From the moment the instrument is taken from its packaging and exposed to irradiance the sensitivity may deviate with time. See the 'non-stability' value (% change in sensitivity per year) given in the radiometer specifications.

Delft, The Netherlands, 04 October 2018

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