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ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	030054110310
PYRANOMETER MODEL	CMP 22
SERIAL NUMBER	110310
CALIBRATION DATE	27 December 2023
INSTRUMENT CLASS	ISO 9060, Class A*
CALIBRATION PROCEDURE	ISO 9847:2023 clause 6, type A1
REFERENCE PYRANOMETER	Kipp & Zonen CM 22 sn REF2 active from 03 April 2023
REFERENCE PYRANOMETER CALIBRATION PROCEDURE	ISO 9846 par5
CALIBRATION LOCATION	Delft The Netherlands
CUSTOMER	Alfred-Wegener-Institut Helmholtz-Zentrum Am Handelshafen 12 27570 Bremerhaven Germany
REMARKS	Instrument condition: The calibration item was received fully functional and did not show any erratic behavior or irregularities during calibration. Instrument changes after last calibration: new outer dom

Delft, The Netherlands, 27 December 2023

J. Mes
(in charge of calibration facility)

Wenjin Xu
(in charge of test)

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Company registered in Delft

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Calibration procedure

The indoor calibration procedure is based on a side-by-side comparison with a reference pyranometer under an artificial sun. A lamp is positioned approximately 1.5 m above the pyranometers producing a vertical beam. The reference and test pyranometer are mounted horizontally on a table which can rotate. The irradiance at the pyranometers is approximately 600 W/m². During the calibration procedure the reference and test pyranometer are interchanged to correct for any non-homogeneity of the beam. Temperature during calibration: 22 °C ± 2 °C.

Hierarchy of traceability

The measurements have been executed using standards for which the traceability to international standards has been demonstrated towards the RvA.

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: 37.04992°, longitude: -2.39084°, altitude: 500m above sea level). Dates of measurements: 09-11 September 2022.
The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 800 W/m² to 1157 W/m² with a mean of 908 W/m² and tilted diffuse radiation intensities from 95 W/m² to 450 W/m² with a mean of 176 W/m². The ambient temperature ranged from 24.2 °C to 37.3 °C with a mean of 33.4 °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). WRR factor of PMO6: 0.998913 (from the last IPC-2021).

This calibration proved that the reference pyranometer has been stable and that the original sensitivity 9.34 μV/(W/m²) ± 0.06 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 W/m² to 1195 W/m² with a mean of 874 W/m². The solar zenith angle varied from 23.5° to 49.8° with a mean of 32.9°. The ambient temperature ranged from 12.6 °C to 26.2 °C 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:9.34 ± 0.06 μV/W/m². The measurements were performed in Davos (latitude: 46.8143°, longitude: 9.8458°, altitude: 1558 m 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 from IPC-2010) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM22 SN 020059 (ventilated with heated air).

SENSITIVITY	9.19 μV/(W/m²) at normal incidence on horizontal pyranometer
UNCERTAINTY	0.08 μV/(W/m²) = 0.87 %

Justification of total instrument calibration uncertainty

The combined uncertainty of the result of the calibration is the positive "root sum square" of the following components.
1. The expanded uncertainty due to random effects and instrumental errors during the calibration of the reference CM 22 is ±0.06/9.34 = ±0.64% (k=2). See traceability text.
2. The expanded uncertainty of the transfer procedure (calibration by comparison) is estimated to be ±0.5% (k=2).
3. The estimated uncertainty of the WRR relative to SI: ±0.3% (k=2).
The expanded uncertainty is: $\sqrt{(0.64\%^2 + 0.5\%^2 + 0.3\%^2)} = \pm 0.87\%$ (k=2).

The reported expanded uncertainty is based on the standard uncertainty of the measurement multiplied by a coverage factor k, such that the coverage probability corresponds to approximately 95%. The standard uncertainty has been determined in accordance with EA 04/2.

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.

Expected instrument impedance**: 28 Ω ± 2.0 Ω

* Instruments issued before October 2018 are classified conform to ISO 9060:1990.
** This impedance estimate can be helpful to check wire connections for shorts or open connections.

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MEASUREMENT REPORT
PYRANOMETER

Routine measurement of directional error during final inspection

The cosine error of a pyranometer type CMP 22 is measured by the following routine:

The pyranometerbase is placed against the vertical turntable of a goniometer in the parallel (0,5°) beam of a sunsimulator. The output voltage U(z) is measured at incidence (Zenith) angles 0°,40°, 60°, 70° and 80° coming in over Azimuth south (cable pointing to North). A shutter is used to block the beam and obtain dark signals. These zero offset signals are subtracted from the irradiance readings.

For Zenith angle 40° and 70° all four Azimuth angles are measured; South, East, North and West and the cosine error is calculated.

The applied formula for the relative cosine error is:

U(0°) Pyranometer output voltage at normal incidence
U(z) Pyranometer output voltage at angles (z)
Zero(z) Dark signal at angles (z)

$$\frac{\frac{(U(z)+U(-z))}{2}-\text{zero}(z)}{\left(\frac{U(0°)+U(0°)}{2}-\text{zero}(z)\right)\cdot\cos(z)}\cdot 100\%$$

Formula 1.

Relative directional response error at zenith angle to 0° in %

Zenith angle	South	East	North	West
40	0.40	-0.05	0.38	0.14
60	0.30			
70	0.12	0.01	-1.33	0.46
80	-0.12			

Next, the error in W/m² is calculated assuming a direct beam irradiance of 1000 W/m²

Absolute directional response error for 1000 W/m² beam radiation in W/m²

Zenith angle	South	East	North	West
40	3.04	-0.39	2.88	1.08
60	1.48			
70	0.42	0.04	-4.57	1.59
80	-0.21			

PYRANOMETER MODEL: CMP 22 SERIAL NUMBER: 110310