OTT HydroMet B.V. | Delftechpark 36 | 2628 XH Delft | The Netherlands | +31 15 2755 210 | solar-info@otthydromet.com | www.otthydromet.com

ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	025234080012
PYRANOMETER MODEL	CMP 11
SERIAL NUMBER	080012
CALIBRATION DATE	20 December 2021
INSTRUMENT CLASS	ISO 9060, Class A (Sec. Standard)*
CALIBRATION PROCEDURE	ISO 9847 par5.3.2, A3
REFERENCE PYRANOMETER	Kipp & Zonen CMP 21 sn 110734 active from 01 January 2021
REFERENCE PYRANOMETER CALIBRATION PROCEDURE	ISO 9846 par5
CALIBRATION LOCATION	Delft The Netherlands
CUSTOMER	Briese Schiffahrts GmbH and Co. KG Forschungsschifffahrt Hafenstrasse 12 26789 Leer 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: The CMP11's housing is replaced

Delft, The Netherlands, 20 December 2021

Joop Mes

J. Mes
(in charge of calibration facility)

V. Tromp

V. Tromp
(in charge of test)

OTT HydroMet B.V.
Company registered in Delft

Trade register no.: 27239004
VAT no.: NL0055.74.857.B.01
Member of HMEI

EUR payments
Deutsche Bank AG
IBAN: NL70 DEUT 0265 2482 48
BIC: DEUTNL2A

USD payments only
Deutsche Bank AG
IBAN: DE60100701000162416200
BIC: DEUTDEBB101

OTT HydroMet B.V. | Delftechpark 36 | 2628 XH Delft | The Netherlands | +31 15 2755 210 | solar-info@otthydromet.com | www.otthydromet.com

ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER 025234080012

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 Delft, The Netherlands (latitude: 51.9969°, longitude: 4.3863°, altitude: 10m above sea level). Dates of measurements: 22-24 June 2020.
The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 835 W/m² to 1136 W/m² with a mean of 995 W/m² and tilted diffuse radiation intensities from 89 W/m² to 254 W/m² with a mean of 151 W/m². The ambient temperature ranged from +19.0 °C to +29.9 °C with a mean of +23.9 °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: 0.99787 (from the last IPC-2015).

This calibration proved that the reference pyranometer has been stable and that the original sensitivity 8.49 μV/(W/m²) ± 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 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 436 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:8.49 ± 0.11 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 the last international Pyrheliometer Comparison, IPC-2015) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM22 SN 020059 (ventilated with heated air).

SENSITIVITY	8.91 μV/(W/m²) at normal incidence on horizontal pyranometer
UNCERTAINTY	0.13 μV/(W/m²) = 1.42 %
IMPEDANCE	31 ± 1.5 Ω

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 CMP 21 is ±0.11/8.49 = ±1.3% (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: $\sqrt{(1.3\%^2 + 0.5\%^2 + 0.3\%^2)} = \pm 1.42\%$ (k=2).

The resistance measurement uncertainties are due to the PXI 4065 uncertainty in the 100 Ω range: 150ppm of range (=15mΩ) the cable resistance (estimated 0.1 Ω) and due to the electrothermal effect the measurement current in the thermal detector of the pyranometer. This was found to be a resistance error of 1.5 Ω, which results in a total resistance uncertainty of $\sqrt{(0.015^2+0.1^2+ 1.5^2)} = 1.5\ \Omega$ or 5%.

The PXI 4065 is calibrated by National Instruments Hungary, on 2 september 2020 at a temperature of 23.0 °C, under ISO/IEC 17025:2017 accreditation. This calibration is traceable to NIST and/or other National Measurement Institutes (NMI's).

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.

* from October 2018 the classification conforms to ISO 9060:2018. Instruments issued before that date conform to ISO 9060:1990.

RvA is member of the European Co-operation for Accreditation (EA) and is one of the signatories to the EA Multilateral Agreement (MLA) and to the ILAC Mutual Recognition Arrangement (MRA) for the mutual recognition of calibration certificates.

OTT HydroMet B.V.
Company registered in Delft

Trade register no.: 27239004
VAT no.: NL0055.74.857.B.01
Member of HMEI

EUR payments
Deutsche Bank AG
IBAN: NL70 DEUT 0265 2482 48
BIC: DEUTNL2A

USD payments only
Deutsche Bank AG
IBAN: DE60100701000162416200
BIC: DEUTDEBB101