ISO/IEC 17025 CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	021382200195
PYRANOMETER MODEL	SMP21-V
SERIAL NUMBER	200195
CALIBRATION DATE	15 July 2020
INSTRUMENT CLASS	ISO 9060, Class A (Sec. Standard)*
CALIBRATION PROCEDURE	ISO 9847 par5.3.2, A3
REFERENCE PYRANOMETER	Kipp & Zonen CMP 21 sn 070115 active from 01 January 2020
REFERENCE PYRANOMETER CALIBRATION PROCEDURE	ISO 9846 par5
CALIBRATION LOCATION	Delft The Netherlands
CUSTOMER	
REMARKS	

Delft, The Netherlands, 15 July 2020

J. Mes
(in charge of calibration facility)

F. de Wit
(in charge of test)

Kipp & Zonen B.V.
Trade name: OTT HydroMet
Company registered in Delft

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

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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 fed by an AC voltage stabiliser. It embodies a 150 W Metal-Halide high-pressure gas discharge lamp and a reflector with a diameter of 16.2 cm. The lamp is positioned 1 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 500 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: 37.094°, longitude: -2.3547°, altitude: 503m above sea level). Dates of measurements: 2019 June 13-14, 17-18.
The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 635 W/m² to 1050.9 W/m² with a mean of 1011.6 W/m² and tilted diffuse radiation intensities from 88.2 W/m² to 183.7 W/m² with a mean of 122.0 W/m². The ambient temperature ranged from +19.9 °C to +32.0 °C with a mean of +26.8 °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 0807. The PMO6 is calibrated against the World Standard Group (WSG), maintained at the WRC Davos every International Pyrheliometer Comparison (IPC). WRR factor of PMO6: 1.00444 (from the last NPC-2019).

This calibration proved that the reference pyranometer has been stable and that the original sensitivity 8.75 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 665 W/m² to 1082 W/m² with a mean of 897 W/m². The solar zenith angle varied from 25.3° to 50.0° with a mean of 33.7°. The ambient temperature ranged from +15.3 °C to +25.3 °C with a mean of +20.7 °C. The sensitivity calculation is based on 623 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:8.75 ± 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: 15-19, 25 July 2014. 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, NPC-2019) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM22 SN 020059 (ventilated with heated air).

SENSITIVITY 10.37 µV/(W/m²) at normal incidence on horizontal pyranometer

UNCERTAINTY 0.14 µV/(W/m²) = 1.39 %

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 ±0.11/8.75 = ±1.26% (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: $\sqrt{(1.26\%^2 + 0.5\%^2 + 0.3\%^2)} = \pm 1.39\%$ (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 7 november 2018 at a temperature of 22.7 °C, under ISO 17025:2005 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.

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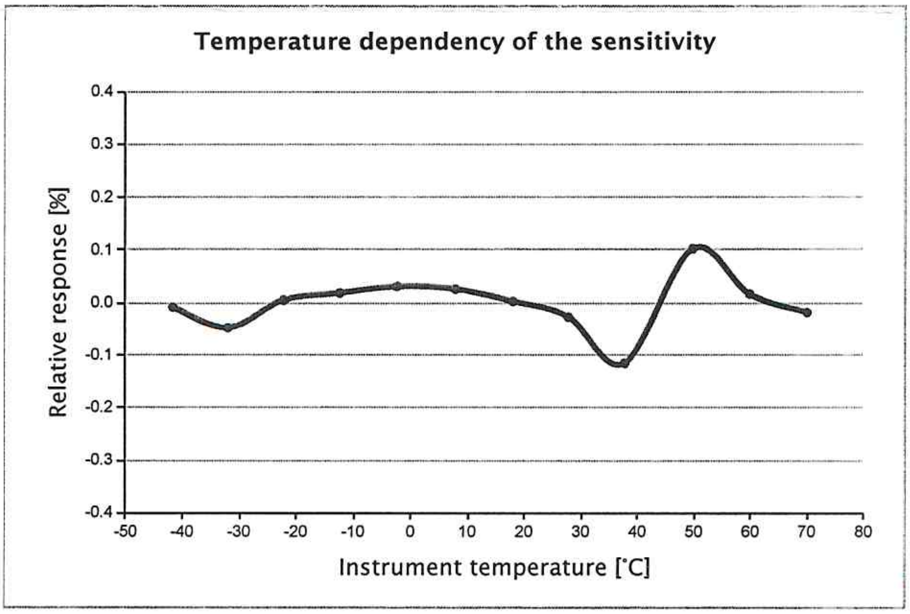
MEASUREMENT REPORT
PYRANOMETER

Routine measurement of temperature dependency during final inspection

PYRANOMETER TYPE	SMP21-V
SERIAL NUMBER	200195
DATE OF MEASUREMENT	08 May 2020
PERFORMED BY	M. Reij
PROCEDURE	The pyranometer is mounted inside the climate chamber and illuminated with a white light source under normal incidence. A CMP22 pyranometer outside the chamber is used to monitor the lamp stability. The pyranometer is tested over a temperature range from 70 °C down to -40 °C in steps of 10 °C. The relative temperature dependency is plotted below. The measurement uncertainty of this characterisation is ±0.1% (k=2).



Instrument temperature [°C]	Relative response [%]
-42	-0.01
-32	-0.05
-22	0.01
-12	0.02
-2	0.03
8	0.03
18	0.00
28	-0.03
38	-0.12
50	0.10
60	0.02
70	-0.02

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Meteorology Division of OTT HydroMet

MEASUREMENT REPORT

PYRANOMETER

Routine measurement of directional error during final inspection

Mean cosine error of each new pyranometer type SMP 21 is measured by a simple routine.

Routine:

The pyranometerbase is placed against the vertical turntable of a goniometer in the parallel (0,5°) beam of a sunsimulator.
Voltage output U(z) is measured for beam incidence (zenith) angles of 0°,40°, 60°, 70° and 80° coming in over azimuth south (cable pointing to North).
Next the pyranometer output U(-z) is measured for incidence angles of -80°, -70°, -60°, -40° and 0° consequently for azimuth south. The dark signal is measured at the beginning of the routine in the middle and at the end. For each beam incident angle the dark signal is interpolated.

During the SMP 21 measurement cycle, a check is done on the azimuth error at 40° and 70° by measuring voltages for azimuth-directions S, E, N and W . Also at -70° and -40° this azimuth error is measured and the mean of both azimuth measurements cancels out the eventual error in the 0° position.

With the extended procedure at both 40° and -40° and 70° and -70° the specific cosine error for 8 azimuth directions (40° S, W, N and E and 70° E, N, W, S) can be calculated according to formula 1 and verified whether it is within ± 10 W/m².

The applied formula for the relative cosine error is:

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

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

Formula 1.

Relative cosine error at zenith angle in %

Zenith angle	South	East	North	West
40	-0.21	0.15	0.08	-0.53
60	-0.55			
70	-0.44	-0.14	0.13	-0.71
80	0.09			

Absolute cosine error for 1000 W/m² beam radiation in W/m²

Zenith angle	South	East	North	West
40	-1.60	1.17	0.61	-4.03
60	-2.73			
70	-1.49	-0.49	0.46	-2.43
80	0.16			

PYRANOMETER MODEL: SMP 21 SERIAL NUMBER: 200195