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

CALIBRATION CERTIFICATE

CERTIFICATE NUMBER	: 023613210132
CALIBRATION DATE	: 19 July 2021
PYRGEOMETER MODEL	: SGR4V
SERIAL NUMBER	: 210132
REFERENCE PYRGEOMETER	: Kipp & Zonen CGR 4 sn 100280 active from January 1, 2021
BODY TEMPERATURE SENSOR	: YSI 44031
SENSITIVITY	: 16.38 ± 0.67µV/W/m²
AMBIENT TEMPERATURE	: Between 15.6ºC and 16.9ºC, average 16.4ºC
IN CHARGE OF TEST:	: A.G. Partosoebroto

CALIBRATION PROCEDURE

The pyrgeometer is calibrated outdoors at Kipp & Zonen under a mainly clear sky during nighttime. The instrument is installed on a horizontal platform next to the reference CGR 4. Both the pyrgeometer thermopile output (Uemf) and body temperature (T_b) are measured at one second intervals and compressed to one-minute average values.
The calibration factor of the pyrgeometer is determined by the method of the best curve fit to the CGR 4 reference signal. The downward long wave radiation is calculated using the pyrgeometer algorithm ($Ld = Uemf / S + \sigma Tb^4$). Special measurement criteria are taken into account to calculate the best curve fit, under which:

- The sum of all measurement periods must be at least 4 hours.
- Net radiation exchange with the atmosphere, at least -40 W/m².
- Experimental deviation (2σ) representing absolute values within ±0.2 µV/W/m².
- Experimental deviation (2σ) representing relative values within ±3 %.
- Deviation of downward long wave radiation (Ld) to reference is ±5 W/m² maximum.
- Body temperature (Tb) difference with respect to the reference pyrgeometer is ±0.5 ºC maximum.

HIERARCHY OF TRACEABILITY

This reference pyrgeometer was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG 4 FT004 and CG 4 010535) of the IR-Centre at PMOD/WRC. The comparison is made during night time with cloudy and cloud-free situations. Radiation and temperature conditions during the calibration:

Long wave downward radiation (Ld):	240 to 317	W/m²
Net radiation:	-101 to -73	W/m²
Pyrgeometer body temperature:	1.6 to 16.7	˚C
Integrated water vapour (IWV)	10.2 to 23.6	mm
Measurement period (71 days):	30th of June 2020 to 18th of November 2020.	

From the measurements the sensitivity factor S is determined by using the standard Albrecht et al. relation (see below), which involves the pyrgeometer signal U_{emf} and the body temperature T_b of the pyrgeometer. Body temperature is determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors.
The Ld irradiance is calculated using the following equation: $Ld = (U_{emf}/S) + \sigma T_b^4$ The retrieved sensitivity S of the reference pyrgeometer and its expanded uncertainty (2σ = 95% level of confidence) are 11.30 ± 0.39 µV / Wm⁻²

JUSTIFICATION OF TOTAL INSTRUMENT CALIBRATION UNCERTAINTY:

The expanded (95%) calibration uncertainty is the root sum square of two uncertainties:

- The systematic uncertainty, this includes uncertainty of voltage (±0.012mV) and temperature (±0.11K) measurement with the data logger. The uncertainty of the sensitivity of the reference sensor (±0.39 µV / Wm⁻²) is also included.
- The statistical uncertainty due to experimental deviations during the comparison outdoors. The magnitude is 2 x the standard deviation of the distribution of the > 240 individual 1-minute averaged observations.

Notice
The calibration certificate supplied with the instrument is valid from the date of shipment to the customer. 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 will deviate with time. See also the 'non-stability 'performance (max. sensitivity change / year) given in the radiometer specification list.

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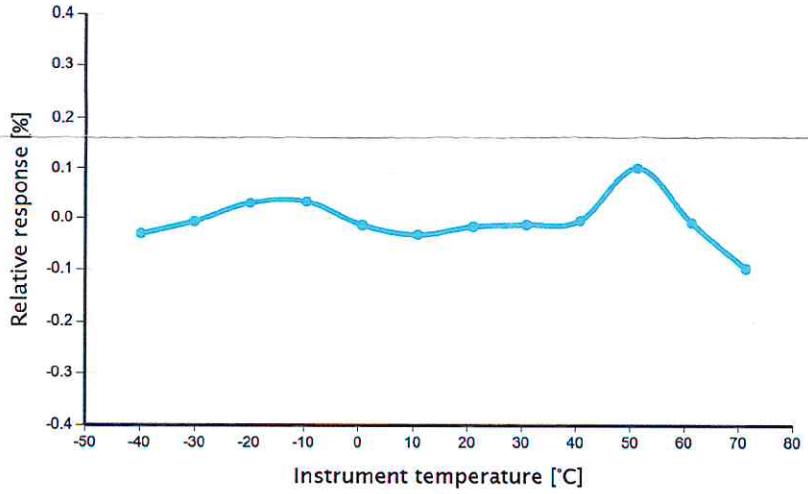
MEASUREMENT REPORT PYRGEOMETER

Routine measurement of temperature dependency during final inspection

PYRGEOMETER TYPE	SGR4-V
SERIAL NUMBER	210132
DATE OF MEASUREMENT	22 January 2021
PERFORMED BY	J.P. Vink
PROCEDURE	The pyrgeometer 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 pyrgeometer 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 [%]
-40	-0.03
-30	-0.01
-20	0.03
-10	0.03
1	-0.01
11	-0.03
21	-0.02
31	-0.01
41	0.00
51	0.10
61	-0.01
71	-0.10