HydroMet

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CALIBRATION CERTIFICATE
LONG WAVE DETECTOR

CERTIFICATE NUMBER	112019121038
CNR4 SERIAL NUMBER	121038
SENSITIVITY UPPER SENSOR	6.83 μV/W/m²
SENSITIVITY LOWER SENSOR	5.48 μV/W/m²
IMPEDANCE	60 Ω (typical)
REFERENCE PYRGEOMETER	Kipp & Zonen CGR 3 sn New York1 active from 09 January 2018

Calibration procedure

The reference and test pyrgeometer are mounted horizontally on a table under an extended warm plate (67 °C). The table can rotate to exchange the positions of both instruments. The net irradiance at the pyrgeometers is approximately 150 W/m². The indoor procedure is based on a sequence of simultaneous readings. After 60 s exposure to the warm plate, the output voltages of both pyrgeometer are integrated 30 s. Next; both pyrgeometers are covered by a blackened "shutter" with stable "room temperature". After 60 s both signals are integrated again during 30 s. The resulting two "zero" signals are subtracted from the former signals to get comparable responses. In this way the procedure compensates for temperature differences between both pyrgeometers. Next the pyrgeometer positions are interchanged by rotation of the table and the procedure is repeated. The mean of former and latter responses is compared to derive the sensitivity figure of the test pyrgeometer. In this way asymmetry in the warm plate configuration and IR environment is cancelled out. The preliminary sensitivity figure is used as input in a spreadsheet which calculates the desired parallel resistors for each pyrgeometer to trim its sensitivity to a selected value.

Hierarchy of traceability

The reference CGR 3 has been compared against a reference pyrgeometer CG 4 under mainly clear sky conditions during night time at Kipp & Zonen, Delft Holland . (On his turn the CG 4 was calibrated outdoors 12th of August to 1st of November 2017 at the IR-centre of the World Radiation Center Davos against their pyrgeometer reference group during 33 measurement days.)
The reference CGR 3 and CG 4 were placed horizontally side by side. During the calibration period on 20 November 2017 the (outgoing) radiation signal (U / S) ranged from -98 to -71 W/m². The instrument temperatures ranged from +1.4 to +15.9°C with a mean of +11.4°C. The pyrgeometer thermopile outputs (U_{CG4}, U_{CGR3}) and body temperatures (T_{CG4}, T_{CGR3}) were measured every second by a COMBILOG 1020 data logger and averages of 60 measurements have been logged as 1 min. values. Later on the downward radiation (L_d) can be determined with the formula:

$$L_d = U_{CG4}/S_{CG4} + 5.67 \cdot 10^{-8} \cdot T_{CG4}{}^4$$

For the CG 4 sn 010536 a sensitivity S_{CG4} of 8.85 ± 0.30 μV/W/m² has been applied and with its voltage U_{CG4} and temperature T_{CG4} data the reference L_d is calculated ranging, from +248to +319W/m². For the reference CGR 3 a one minute average sensitivity S_{CGR3} is calculated with the formula:

$$S_{CGR3} = U_{CGR3} \cdot (L_d - 5.67 \cdot 10^{-8} \cdot T_{CGR3}{}^4)^{-1}$$

The final S_{CGR3} is the average of one minute S_{CGR3}'s determined in periods with a net IR signal < -40 W/m² (Clear sky). The sum of all periods must be at least 4 hours. The CGR 3 sn New York1 sensitivity and its calculated expanded uncertainty are: 12.20 ± 0.30 μV/W/m².

Justification of total instrument calibration uncertainty

The expanded (95% probability) calibration uncertainty is the "root sum square" of two uncertainties:
1. The expanded uncertainty due to random effects during the comparison outdoors at Kipp & Zonen Delft partly due to different instrumental properties of the reference CGR 3 and the reference CG 4 and partly due to the datalogger voltage and temperature (resistance) measurement uncertainties is: ±0.30/12.20 = ±3.5%. This includes the uncertainty in the calibration of the reference CG 4 as given by the in Davos.
2. The expanded uncertainty of the transfer procedure (calibration by comparison) is estimated to be ±4%. This is mainly due to deviations between the spectral transmittance of the window of the reference and the window of the test pyrgeometer and due to their different TC.
The estimated combined expanded (95%) uncertainty is $\sqrt{3.5^2 + 4^2} = \pm 5.3\%$.

Delft, The Netherlands, 17 November 2019

Paul Delisi

Paul Delisi
(in charge of calibration facility)

Khoi Tran

Khoi Tran
(in charge of test)

CALIBRATION CERTIFICATE
SHORT WAVE DETECTOR

CNR4 SERIAL NUMBER	121038
SENSITIVITY UPPER SENSOR	14.56 μV/W/m²
SENSITIVITY LOWER SENSOR	14.17 μV/W/m²
IMPEDANCE	60 Ω (typical)
REFERENCE PYRANOMETER	Kipp & Zonen CMP 3 sn New York 1 active from 01 August 2018
CLASSIFICATION	ISO 9060, Second Class*

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 above the pyranometers producing a vertical beam. The reference and test pyrano-meters 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. This procedure is in accordance with ISO 9847, Type IIc.

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: 2018, 8, 10-12 June.
The receiver surface was pointed directly at the sun using a solar tracker. During the comparisons, the instrument received tilted global radiation intensities from 1008 to 1154 with a mean of 1008 W/m² and tilted diffuse radiation intensities from 82 to 197 with a mean of 131 W/m². The ambient temperature ranged from 22.6 to 29.8 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 15.08 ± 0.39 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 639 to 1196 with a mean of 875 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 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:15.08 ± 0.39 μV/W/m². The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1558m above sea level). Dates of measurements: June 24, 30 July 1, 2 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 3 as given by the World Radiation Center in Davos is ±0.39/15.08 = ±2.59%. (See traceability text).
2. Also 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: $\sqrt{(2.59^2+0.5^2)}$ = ±2.63%.

Delft, The Netherlands, 15 November 2019

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Notice

The calibration certificate supplied with the instrument is 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.

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