CALIBRATION CERTIFICATE

SHORT WAVE DETECTOR

CNR 4 SERIAL NUMBER	:	100264
SENSITIVITY UPPER SENSOR	:	17.71 µV/W/m²
SENSITIVITY LOWER SENSOR	:	17.67 µV/W/m²
IMPEDANCE	:	60 Ohm (typical)
REFERENCE PYRANOMETER	:	Kipp & Zonen CMP 3 sn071176 active from January 6, 2010

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 cm. The reflector is 1 m above the pyranometers producing a vertical beam. The reference and test pyranometers are mounted horizontally on a table, which can rotate. The irradiance at the pyranometers is approx. 500 W/m². During the calibration procedure the reference and test pyranometer are interchanged to correct for any non-homogeneity of the beam. The dark offsets of both pyranometers are measured before and after the interchange and taken into account. The preliminary sensitivity figure is used as input in a spreadsheet which calculates the desired parallel resistors for each pyranometer to trim its sensitivity to a selected value.

HIERARCHY OF TRACEABILITY:

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 measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1588 m above sea level). The readings are referred to the World Radiometric Reference (WRR) as stated in the WMO Technical Regulations. The originally estimated uncertainty of the WRR relative to SI is ±0.3%. The inclination of the receiver surfaces versus their horizontal position were set to 0.0 degrees, the instrument signal wire to the north. During the comparisons, the instrument received global radiation intensities from 636 to 958 with a mean of 822 W/m2. The angle between the solar beam and the normal of the receiver surface varied from 27.7 to 50.0 with a mean of 38.4 degrees. The ambient temperature ranged from +13.8 to +25.9 with a mean of +21.8°C. The sensitivity calculation and the single measurements deviation (σ) are based on 1083 individual measurements.

The obtained sensitivity value and its expanded uncertainty (95% level of confidence) are valid for similar conditions and are: 11.30 ± 0.38 µV/W/m² (but is corrected by Kipp & Zonen to 11.44 µV/W/m². See "correction applied" below.) Dates of measurements: 2009, July 27 - 30, August 5, 6, 18 - 20, 24. Global radiation data were calculated from the direct solar radiation as measured with the absolute cavity pyrheliometer PMO2 (member of the WSG, WRR-Factor: 0.998618, based on the last International Pyrheliometer Comparison IPC-2005) and from the diffuse radiation as measured with a continuous disk shaded pyranometer Kipp & Zonen CM 22 sn020059 with sensitivity 8.91 µV/W/m² (ventilated with heated air, instrument-wire to the north).

CORRECTION APPLIED : +1.2 %

This correction was necessary to correct for the mean directional errors of the reference CMP 3 in Davos. This error is estimated at Kipp & Zonen measuring the cosine error for the mean angle of incidence at azimuth S-30° and S+30°. The reference CMP 3 now measures the vertical directed beam of the indoor calibration facility more correctly.

JUSTIFICATION OF PYRANOMETER CALIBRATION UNCERTAINTY:

The combined uncertainty of the result of the calibration is the positive "root sum square" of three 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 ±0.38/11.30= ±3.36 %. (See traceability text).

2. The uncertainty in the correction for the systematic effect of a directional error (cosine error) during the calibration in Davos. Based on experience this cosine error can be estimated with an expanded uncertainty of ±0.5%.

3. 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 three uncertainties: $\sqrt{(3.36^2 + 0.5^2 + 0.5^2)} = \pm 3.4\%$.

IN CHARGE OF TEST : M. Elshout, Date: 12 May 2010 Kipp & Zonen, Delft, Holland

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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CALIBRATION CERTIFICATE

LONG WAVE DETECTOR

CERTIFICATE NUMBER	:	003714100264
CNR 4 SERIAL NUMBER	:	100264
SENSITIVITY UPPER SENSOR	:	8.88 μV/W/m²
SENSITIVITY LOWER SENSOR	:	10.05 μV/W/m²
IMPEDANCE	:	60 Ohm (typical)
REFERENCE PYRGEOMETER	:	Kipp & Zonen CG 3 sn030004 active from February 24, 2010

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 30s. 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 CG 3 has been calibrated to the reference pyrgeometer CG 4 under mainly clear sky conditions during nighttime at Kipp & Zonen, Delft Holland. (On his turn the CG 4 has been calibrated outdoors September 22 to November 1, 2009 at the IR-centre of the World Radiation Center Davos, to their pyrgeometer reference group during 27 measurement days.)

The reference CG 3 and CG 4 were placed horizontally side by side. During the calibration period on on February 17, 2010, the (outgoing) radiation signal (U / S) ranged from - 79 to - 74 W/m². The instrument temperatures ranged from -2.0° to +0.3°C with a mean of -0.8°C. The pyrgeometer thermopile outputs ($U_{CG\,4}$, $U_{CG\,3}$) and body temperatures ($T_{CG\,4}$, $T_{CG\,3}$) 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:

$$L_d = \frac{U_{CG\ 4}}{S} + 5.67 \cdot 10^{-8} \cdot T_{CG\ 4}{}^4$$

For the reference CG 4 sn010536 a sensitivity of 9.03 ±0.28 μV/W/m² was applied and with its voltage UCG 4, and temperature TCG 4 data the reference Ld is calculated, ranging from +230 to +240 W/m². For the reference CG 3 a one minute average sensitivity SCG 3 is calculated with the formula:

$$S_{CG\ 3} = U_{CG\ 3} \cdot \left(L_d - 5.67 \cdot 10^{-8} \cdot T_{CG\ 3}{}^4\right)^{-1}$$

The final $S_{CG\,3}$ is the average of one minute $S_{CG\,3}$'s determined in periods with a net IR signal < -40 W/m² (Clear sky). The sum of all periods must be at least 6 hours. The calculated CG 3 sn030004 sensitivity and expanded uncertainty are: 13.65 ± 0.54 μV/W/m².

JUSTIFICATION OF PYRGEOMETER 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 CG 3 and the reference CG 4 and partly due to the datalogger voltage and temperature (resistance) measurement uncertainties is: ±0.54/13.65= ±3.96%. This includes the uncertainty in the calibration of the reference CG 4 as given by the WRC 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 $\sqrt{(3.96^2 + 4^2)} = \pm 5.6\,\%$.

IN CHARGE OF TEST : M. Elshout, Date: 12 May 2010 Kipp & Zonen, Delft, Holland

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