

CERTIFICATE NUMBER : 015704170223  
 CALIBRATION DATE : 17 July 2017  
 PYRGEOMETER MODEL : CGR 4  
 SERIAL NUMBER : 170223  
 REFERENCE PYRGEOMETER : Kipp & Zonen CGR 4 sn 100280 active from Januari 1, 2017  
 BODY TEMPERATURE SENSOR : PT100  
 SENSITIVITY :  $10.05 \pm 0.39 \mu\text{V}/\text{W}/\text{m}^2$   
 AMBIENT TEMPERATURE : Between 14.0°C and 16.0°C, average 14.7°C  
 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 ( $U_{\text{emf}}$ ) 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 ( $L_d = U_{\text{emf}}/S + \sigma T_b^4$ ). 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  $-40 \text{ W}/\text{m}^2$ .
- Experimental deviation ( $2\sigma$ ) representing absolute values within  $\pm 0.2 \mu\text{V}/\text{W}/\text{m}^2$ .
- Experimental deviation ( $2\sigma$ ) representing relative values within  $\pm 3 \%$ .
- Deviation of downward long wave radiation ( $L_d$ ) to reference is  $\pm 5 \text{ W}/\text{m}^2$  maximum.
- Body temperature ( $T_b$ ) difference with respect to the reference pyrgeometer is  $\pm 0.5 \text{ }^\circ\text{C}$  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 ( $L_d$ ): 255 to 319  $\text{W}/\text{m}^2$   
 Net radiation: -97 to -72  $\text{W}/\text{m}^2$   
 Pyrgeometer body temperature: 4.1 to 17.3  $^\circ\text{C}$   
 Integrated water vapour (IWV) 10.2 to 20.3 mm  
 Measurement period (42 days): 13<sup>th</sup> of August 2016 to 26<sup>th</sup> of November 2016.

From the measurements the sensitivity factor  $S$  is determined by using the standard Albrecht et al. relation (see below), which involves the pyrgeometer signal  $U_{\text{emf}}$  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  $L_d$  irradiance is calculated using the following equation:  $L_d = (U_{\text{emf}}/S) + \sigma T_b^4$ . The retrieved sensitivity  $S$  of the reference pyrgeometer and its expanded uncertainty ( $2\sigma = 95\%$  level of confidence) are  $11.27 \pm 0.38 \mu\text{V} / \text{Wm}^2$ .

#### 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 ( $\pm 0.012 \text{ mV}$ ) and temperature ( $\pm 0.11 \text{ K}$ ) measurement with the data logger. The uncertainty of the sensitivity of the reference sensor ( $\pm 0.38 \mu\text{V} / \text{Wm}^2$ ) 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.

## MEASUREMENT REPORT

### PYRGEOMETER

Routine measurement of temperature dependency during final inspection.

DATE OF MEASUREMENT : 20/07/2017

PERFORMED BY : F. de Wit

PYRGEOMETER TYPE : CGR 4

SERIAL NUMBER : 170223

**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 lamp stability.

The pyrgeometer is tested in a temperature range over 50 °C down to -20 °C in steps of 10 °C. The relative temperature dependency is plotted below

