CALIBRATION CERTIFICATE
NR. 2007-C-01

Instrument type: **Eppley PSP**

Serial No: **26953F3**

Owner: **Optimare, Bremerhaven, Germany**

This pyranometer was compared with the sun and sky radiation as source under mainly clear sky conditions using the "continuous sun-and-shade method". The direct solar radiation is determined using the PMO2, member of the World Standard Group (WSG) and the diffuse radiation is measured using the shaded standard pyranometer of the World Radiation Center (WRC). The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1588m). 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 ranging from 637 Wm^{-2} to 1093 Wm^{-2}, with a mean of 866 Wm^{-2}. The angle between the solar beam and the normal of the receiver surface varied from 25.2 degrees to 49.9 degrees, with a mean of 34.0 degrees. The instrument temperature ranged from +16.6°C to +25.7°C, with a mean of +22.6°C. The sensitivity calculation and the single measurements deviation (σ) are based on 352 individual measurements. The obtained sensitivity value is valid for similar conditions.

Sensitivity: $$S = (\ 9.01 \pm 0.12\ )\ \mu V W^{-1} m^2$$

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Reference: WRR represented by the absolute pyrheliometer PMO2

WRR-Factor of PMO2: 0.998618
(from the last International Pyrheliometer Comparison, IPC-2005)

Pyranometer CM22 020059 with calibration factor 8.91
(ventilated with heated air, automatic shading disk, instrument-wire to the north)

Dates of measurements: 2007, July 13 - 18

In charge of measurements: In charge of calibration:

Ch. Thomann   Dr. W. Finsterle   Prof. Dr. W.K. Schmutz

                                                                     Director PMOD/WRC

Davos Dorf, Friday, 20. July 2007

Calibration Certificate

Customer	**Optimare Sensorsystem AG** **Am Luneort 15a** **27572 Bremerhaven** **Deutschland**
Model	**Precision infrared Radiometer,** **modified, with 3 dome thermistors at 45°**
Manufacturer	**The Eppley Laboratory, Inc.**
Serial No.	**26956F3**
Date of calibration	**July 12, 2007 to July 16, 2007**

Reference instruments	**Eppley PIR 31463F3**
used for the calibration	**Eppley PIR 31464F3**
	Kipp&Zonen CG4 FT004
	Kipp&Zonen CG4 030669

These reference instruments form the **World Infrared Standard Group (WISG)** and are traceable to the **Absolute Sky Scanning Radiometer (ASR)**.

The measurements, the uncertainties with confidence probability and calibration methods are given on the following page and are part of the certificate.

Davos Dorf, 16 July, 2007

D. Bühlmann   Dr. J. Gröbner
(In charge of calibration)   (Head of the IR calibration centre)

Calibration procedure:

This instrument was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG4 FT004, and CG4 030669) of the IR-Centre at PMOD/WRC. The comparison is made during nighttime with cloudy and cloud-free situations. The pyrgeometer was installed in a PMOD-VHS ventilation unit with a heated air flow around the dome.

From the measurements the sensitivity factor **C** is determined by using the standard relation (shown below), which involves the pyrgeometer signal U_{emf}, the dome temperature T_D and body temperature T_B of the pyrgeometer. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors. The dome temperature T_D is calculated from the average of the three dome temperature measurements (N, SE, and SW). The longwave downward irradiance E is calculated using the following equation:

$$E = \frac{U_{emf}}{C} + \sigma T_B^4 - K\sigma(T_D^4 - T_B^4)$$

Sensitivity: **C = 3.57 ☐µV/Wm^{-2}**

                         µ= 0.10 ☐µV/Wm^{-2}

coefficient in use: **K= 3.3**

The coefficient **K** was determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR):	**258 to 318 Wm^{-2}**
Net radiation:	**-4 to-107 Wm^{-2}**
Pyrgeometer body temperature:	**5.7 to 19.3 °C**
Standard deviation of the residuals	**0.4 Wm^{-2}**
Measurement period:	**July 12, 2007 to July 16, 2007**
Measurement days used for the calibration:	**4**

Remarks:

It is recommended to use this pyrgeometer with a shading disc. If the pyrgeometer is used without a shading disk the longwave part of the solar radiation has to be subtracted during daytime measurements.

Calibration Certificate

Customer	**Optimare Sensorsystem AG** **Am Luneort 15a** **27572 Bremerhaven** **Deutschland**
Model	**Precision infrared Radiometer,** **modified, with 3 dome thermistors at 45°**
Manufacturer	**The Eppley Laboratory, Inc.**
Serial No.	**26955F3**
Date of calibration	**July 6, 2007 to July 16, 2007**

Reference instruments used for the calibration	**Eppley PIR 31463F3** **Eppley PIR 31464F3** **Kipp&Zonen CG4 FT004** **Kipp&Zonen CG4 030669**

These reference instruments form the **World Infrared Standard Group (WISG)** and are traceable to the **Absolute Sky Scanning Radiometer (ASR).**

The measurements, the uncertainties with confidence probability and calibration methods are given on the following page and are part of the certificate.

Davos Dorf, 16 July, 2007

D. Bühlmann
(In charge of calibration)

Dr. J. Gröbner
(Head of the IR calibration centre)

This calibration certificate shall not be reproduced except in full, without the written approval of the laboratory.

Calibration procedure:

This instrument was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG4 FT004, and CG4 030669) of the IR-Centre at PMOD/WRC. The comparison is made during nighttime with cloudy and cloud-free situations. The pyrgeometer was installed in a PMOD-VHS ventilation unit with a heated air flow around the dome.

From the measurements the sensitivity factor **C** is determined by using the standard relation (shown below), which involves the pyrgeometer signal U_{emf}, the dome temperature T_D and body temperature T_B of the pyrgeometer. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors. The dome temperature T_D is calculated from the average of the three dome temperature measurements (N, SE, and SW). The longwave downward irradiance E is calculated using the following equation:

$$E = \frac{U_{emf}}{C} + \sigma T_B^4 - K\sigma(T_D^4 - T_B^4)$$

Sensitivity: **C = 4.01 $\Box\mu$V/Wm^{-2}**

μ= 0.11 $\Box\mu$V/Wm^{-2}

coefficient in use: **K= 2.8**

The coefficient **K** was determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR):	**258 to 366 Wm^{-2}**
Net radiation:	**-9 to -111 Wm^{-2}**
Pyrgeometer body temperature:	**6.4 to 20.0 °C**
Standard deviation of the residuals	**0.24 Wm^{-2}**
Measurement period:	**July 06, 2007 to July 16, 2007**
Measurement days used for the calibration:	**6**

Remarks:

It is recommended to use this pyrgeometer with a shading disc. If the pyrgeometer is used without a shading disk the longwave part of the solar radiation has to be subtracted during daytime measurements.

CALIBRATION CERTIFICATE

NR. 2007-C-02

Instrument type: **Eppley PSP**

Serial No: **26954F3**

Owner: Optimare, Bremerhaven, Germany

This pyranometer was compared with the sun and sky radiation as source under mainly clear sky conditions using the "continuous sun-and-shade method". The direct solar radiation is determined using the PMO2, member of the World Standard Group (WSG) and the diffuse radiation is measured using the shaded standard pyranometer of the World Radiation Center (WRC). The measurements were performed in Davos (latitude: 46.8143°, longitude: -9.8458°, altitude: 1588m). 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 ranging from 637 Wm^{-2} to 1093 Wm^{-2}, with a mean of 866 Wm^{-2}. The angle between the solar beam and the normal of the receiver surface varied from 25.2 degrees to 49.9 degrees, with a mean of 34.0 degrees. The instrument temperature ranged from +16.6°C to +25.7°C, with a mean of +22.6°C. The sensitivity calculation and the single measurements deviation (σ) are based on 351 individual measurements. The obtained sensitivity value is valid for similar conditions.

Sensitivity: $$S = (8.08 \pm 0.10)\ \mu VW^{-1}m^2$$

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Reference: WRR represented by the absolute pyrheliometer PMO2

WRR-Factor of PMO2: 0.998618
(from the last International Pyrheliometer Comparison, IPC-2005)

Pyranometer CM22 020059 with calibration factor 8.91
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Dates of measurements: 2007, July 13 - 18

In charge of measurements: In charge of calibration:

Ch. Thomann   Dr. W. Finsterle   Prof. Dr. W.K. Schmutz

                                                             Director PMOD/WRC

Davos Dorf, Friday, 20. July 2007