Calibration Report: Eppley PIR Pyrgeometer

Summary

Calibration Date: July 16, 2009 Calibration Due Date: July 2011

Serial No.	C $\mu V/W/m^2$	u	k1	k2	k3	Cs $\mu V/W/m^2$	K'
26168F3	4.72	0.09	0.0900	1.0088	3.400	N/A	N/A
26181F3	3.86	0.07	0.0600	0.9995	3.000	N/A	N/A

$$E = \frac{U_{emf}}{C}(1 + k_1\sigma T^3_B) + k_2\sigma T^4_B - k_3\sigma(T^4_D - T^4_B) \qquad EQN\ 1$$

Where:

E = Irradiance, W/m^2
U_{emf} = Thermopile output voltage, μV
C = Sensitivity Coefficient, $\mu V/W/m^2$
$k1, k2, k3$ = Correction factors
σ = Stephan-Boltzmann Constant, 5.67 x 10^{-8} $W/m^2 K^4$
T_B = Output of body thermistor YSI 44031 , K
T_D = Output of dome thermistor YSI 44031, K
f = Correction factor for long wave component of direct sun if the instrument is used without a shading disk.
$\Delta T_{S\text{-}N} = (T_{SE} - T_N) + (T_{SW} - T_N)$
T_{SE}, T_N, T_{SW} = Output of dome thermistors, southeast, north and southwest respectively, K
u = Reported expanded uncertainty of measurement

$$\frac{1}{T} = a + b * \log(R) + c * \log(R)^3 \qquad EQN\ 2$$

Where:

T = Temperature in Kelvin
R = Thermistor resistance in Ohm
a,b,c = Constants determined for temperature range -30C - +40C using the nominal resistance to temperature values provided by manufacturer. These coefficients are:
a = 10297.2 * 10^{-7}
b = 2390.6 * 10^{-7}
c = 1.5677 * 10^{-7}

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Abstract

Two Eppley Laboratory, Inc. Precision Infrared Pyrgeometers (PIR) instruments were calibrated. This calibration was performed in order that the instruments comply with specifications set in the Baseline Surface Radiation Network (BSRN) Operator's Manual, V 2.1, 2005. Physikalisch-Meteorolisches Observatorium Davos (PMOD) in Davos-Dorf, Switzerland performed the calibration. The calibration date is 16 July 2009. The serial numbers of the units calibrated were 26168F3 and 26181F3.

1. Introduction

Two Eppley Laboratory, Inc. PIR's were calibrated to meet the 2005 Baseline Surface Radiation Network (BSRN) specifications. PMOD in Davos-Dorf, Switzerland completed these calibration tasks.

2. Results

Calibration results for each instrument are shown in the above summary page along with the governing equations. The use of EQN. 1 with the above tabular values is described in each of the Calibration Certificates provided by PMOD. EQN. 2 is the conversion of resistance to temperature using the Steinhart and Hart equation. The Body and Dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistor. NOTE: EQN. 2 is different from the previous calibration write-ups. Removed Albrecht et al. Single sensitivity factor equation.

3. Discussion

These sensors have been calibrated to permit the measurement of diffuse radiation. Global measurements involve determination of the factor *f*. We do not use the PIR's for global measurements. As of 2005, BSRN targets Downwelling and Upwelling Infrared Radiation measurement uncertainty to be 2% or 3 W/m^2. Field data need to be examined in order to assess the standard uncertainty made by the calibrated instruments.

The single sensitivity factor calibration histories of the two sensors calibrated at PMOD are as follows:

26168F3

Jul. 2009	PMOD	4.72	$\mu V/W/m^2$
Mar. 2003	PMOD	4.39	$\mu V/W/m^2$
Jan. 2002	PMOD	4.38	$\mu V/W/m^2$
Sep. 2000	PMOD	4.26	$\mu V/W/m^2$

26181F3

Jul. 2009	PMOD	3.86	$\mu V/W/m^2$
Jan. 2002	PMOD	3.53	$\mu V/W/m^2$
Dec. 1999	PMOD	3.57	$\mu V/W/m^2$

In the past, these two PIR's were not performed against the WISG(World Infrared Standard Group) of pyrgeomoeters using outdoor calibrations, but with the blackbody in use at PMOD. As later investigations have shown, blackbody calibrations do not give representative calibrations when these pyrgeometers are used for atmospheric longwave radiation measurements. The reason is believed to be with the spectral sensitivity of the pyrgeometer (essentially the spectral dome transmission). Therefore the recommended calibration procedure is to do the calibration with respect to a group of pyrgeometers using outdoor measurements of longwave radiation. The WISG itself was calibrated against the absolute sky scanner of R. Philipona, which was a windowless device. These two PIR's were calibrated using the WISG.

Since this calibration is different from past calibrations, an apples to apples comparison is unachievable unless you perform this most recent calibration with a blackbody, which has been done. Here, the results in both instruments single sensitivity factor, *C*, are within the variability of 2% or less, which did not involve physical changes to the instrument. The variability is 2% or less two different ways: 1) Between the blackbody calibration from this calibration and the previous one and 2) Between the WISG calibration and the blackbody calibration for this particular calibration.

4. Summary

A calibration of two Eppley Laboratory Inc. PIR instruments has been completed. Data analyses have been performed. The calibration factors are presented in the summary table above and in the Calibration Certificates.

These PIR's have been more than 5 years since last calibration. Since then, a new way of calibrating PIR's has been implemented. No apparent performance anomalies are indicated from the single sensitivity factor calibration history of the sensors.

It is recommended to calibrate these instruments yearly but at least every other year.

These calibration factors can be used with these two instruments from 16 July 2009.

Please read the attached calibration documents for additional details.

REFERENCES

Albrecht, B., and S.K. Cox, Procedures for Improving Pyrgeometer Performance, Journal of Applied Meteorology, 16, 179-188, 1977.

Frohlich, C., and R. Philipona, Characterization of pyrgeometers and the accuracy of atmospheric longwave measurements, Ch.,Betz, Applied Optics, 34(9),1598-1605, 1995.

Groebner, Julian, 11 January 2010, personal communication.

McArthur, J.B., World Climate Research Program, Baseline Surface Radiation Network Operations Manual, Version 2.1., 2005.

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Calibration Certificate

No. 2009_066_01

Calibration Item	**Pyrgeometer**	
	Manufacturer	The Eppley Laboratory, Inc.
	Type	Precision Infrared Radiometer, modified with three dome thermistors
	Serial Number	26168f3
Customer	Science Systems and Applications, Inc. (SSA) 1 Enterprise Parkway, Suite 200 Hampton, VA 23666 United States	
Calibration Mark	Label 2009_066_01	
Period of Calibration	June 12 to July 7, 2009	

Davos Dorf, 16 July 2009

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Certificate No. 2009_066_01

Calibration procedure

This instrument was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG4 FT004, and CG4 010535) of the infrared radiometry section of the World radiation Center (WRC-IRS) 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 (see Eq. 1), which involves the pyrgeometer signal U_{emf}, the body temperature T_B and the Dome temperature T_D of the pyrgeometer. Body and Dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistor (see Eq. 2). The longwave downward irradiance *E* is calculated using the following equation:

$$E = \frac{U_{emf}}{C}(1 + k_1 \cdot \sigma T_B^3) + k_2 \cdot \sigma T_B^4 - k_3 \cdot \sigma(T_D^4 - T_B^4) \qquad (1)$$

The Stefan-Boltzmann constant σ was set to the 2006 recommended CODATA value

$$\sigma = 5.6704 \cdot 10^{-8}\ W\ m^{-2}\ K^{-4}$$

The conversion of resistance to temperature used the Steinhart and Hart equation shown below:

$$\frac{1}{T} = a + b \cdot \log(R) + c \cdot \log(R)^3 \qquad (2)$$

where the temperature T is given in Kelvin and the thermistor resistance R is given in Ohm. The constants a, b, and c, were determined for the temperature range -30 °C to +40 °C using the nominal resistance to temperature values provided by the manufacturer. These coefficients are listed below:

$$a = 10297.2 \cdot 10^{-7} \qquad b = 2390.6 \cdot 10^{-7} \qquad c = 1.5677 \cdot 10^{-7}$$

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Calibration results

Sensitivity: $C = 4.72\ \mu V\ W^{-1}\ m^2$

$u = 0.09\ \mu V\ W^{-1}\ m^2$

The sensitivity C was derived using the following pyrgeometer coefficients k_1, k_2 and k_3:

$k_1 = 0.09$ $k_2 = 1.0088$ $k_3 = 3.4$

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%.

Calibrations Remarks

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR)	266 W/m²	to	362	W/m²
Net radiation	-106 W/m²	to	-27	W/m²
Pyrgeometer body temperature	7.5 °C	to	18.8	°C
Residuals (2.5% to 97.5% percentile)	1.0 W/m²			

Measurement period	12 June to 7 July 2009
Measurement days	18

Comments

The coefficients k_1, k_2 and k_3 were determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 °C and +15 °C and pyrgeometer body temperatures between -10 °C and +20 °C.

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Calibration Certificate

No. 2009_066_02

Calibration Item	**Pyrgeometer**	
	Manufacturer	The Eppley Laboratory, Inc.
	Type	Precision Infrared Radiometer, modified with three dome thermistors
	Serial Number	26181F3
Customer	Science Systems and Applications, Inc. (SSA) 1 Enterprise Parkway, Suite 200 Hampton, VA 23666 United States	
Calibration Mark	Label 2009_066_02	
Period of Calibration	June 12 to July 7, 2009	

Davos Dorf, 16 July 2009

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Certificate No. 2009_066_02

Calibration procedure

This instrument was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG4 FT004, and CG4 010535) of the infrared radiometry section of the World radiation Center (WRC-IRS) 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 (see Eq. 1), which involves the pyrgeometer signal U_{emf}, the body temperature T_B and the Dome temperature T_D of the pyrgeometer. Body and Dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistor (see Eq. 2). The longwave downward irradiance *E* is calculated using the following equation:

$$E = \frac{U_{emf}}{C}(1 + k_1 \cdot \sigma T_B^3) + k_2 \cdot \sigma T_B^4 - k_3 \cdot \sigma(T_D^4 - T_B^4) \qquad (1)$$

The Stefan-Boltzmann constant σ was set to the 2006 recommended CODATA value

$$\sigma = 5.6704 \cdot 10^{-8}\ W\ m^{-2}\ K^{-4}$$

The conversion of resistance to temperature used the Steinhart and Hart equation shown below:

$$\frac{1}{T} = a + b \cdot \log(R) + c \cdot \log(R)^3 \qquad (2)$$

where the temperature T is given in Kelvin and the thermistor resistance R is given in Ohm. The constants a, b, and c, were determined for the temperature range -30 °C to +40 °C using the nominal resistance to temperature values provided by the manufacturer. These coefficients are listed below:

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Certificate No. 2009_066_02

Calibration results

Sensitivity: $C = 3.86\ \mu V\ W^{-1}\ m^2$

$u = 0.07\ \mu V\ W^{-1}\ m^2$

The sensitivity C was derived using the following pyrgeometer coefficients k_1, k_2 and k_3:

$k_1 = 0.06$ $k_2 = 0.9995$ $k_3 = 3.0$

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%.

Calibrations Remarks

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR)	266 W/m²	to	362	W/m²
Net radiation	-96 W/m²	to	-14.7	W/m²
Pyrgeometer body temperature	6.2 °C	to	17.1	°C
Residuals (2.5% to 97.5% percentile)	1.0 W/m²			

Measurement period	June 12 to July 7, 2009
Measurement days	18

Comments

The coefficients k_1, k_2 and k_3 were determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 °C and +15 °C and pyrgeometer body temperatures between -10 °C and +20 °C.

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