

Calibration certificate

Pages: 5
Release date: 24-05-2018

Product code **SR30-D1**
Product identification **serial number 2489**
Product type pyranometer
Measurand hemispherical solar radiation
Classification secondary standard (ISO 9060), high quality (WMO-No. 8)

Calibration result

Sensitivity **$S = 9.46 \times 10^{-6} \text{ V}/(\text{W}/\text{m}^2)$**
Calibration uncertainty **$\pm 0.09 \times 10^{-6} \text{ V}/(\text{W}/\text{m}^2)$**

the number following the \pm symbol is the expanded uncertainty with a coverage factor $k = 2$, and defines an interval estimated to have a level of confidence of 95 percent

Reference conditions 20 °C, normal incidence solar radiation, horizontal mounting, irradiance level 1000 W/m²

Measurement process

Metrological characteristic S in [V/(W/m²)]: sensitivity to irradiance in the 300 to 3000 x 10⁻⁹ m range, with 180° field of view angle, valid for reference conditions
Calibration method indoor calibration according to ISO 9847, type IIc
Measurement equipment Hukseflux Solar Radiation Calibration
Uncertainty of the method the expanded uncertainty is $\pm 0.5 \%$

Metrological traceability

Calibration traceability to WRR (World Radiometric Reference)
Calibration hierarchy from WRR through ISO 9846 and ISO 9847, applying a correction (see below) to reference conditions (see above)
Working standard pyranometer type SR20, serial number 5039
Calibration institute PMOD World Radiation Center, Davos, Switzerland
Standard sensitivity 14.60 x 10⁻⁶ V/(W/m²)
Uncertainty of standard $\pm 0.4 \%$ expanded uncertainty with a coverage factor of 2
Uncertainty of correction based on experience the expanded uncertainty is $\pm 0.75 \%$

Evaluation of the uncertainty of the calibration result

Uncertainty calculation the uncertainty is calculated as the square root of the sum of the squares of the reported uncertainties
 $\sqrt{(0.5)^2 + (0.4)^2 + (0.75)^2} = 1.0 \%$

Person performing calibration:
H.E. Brouwer

Date:
18-05-2018

Product certificate

Pages: 5
 Release date: 24-05-2018

Product code **SR30-D1**
 Product identification **serial number 2489**
 Product type pyranometer
 Measurand hemispherical solar radiation
 Classification secondary standard (ISO 9060), high quality (WMO-No. 8)

Calibration result

Sensitivity **$S = 9.46 \times 10^{-6} \text{ V}/(\text{W}/\text{m}^2)$**
 Calibration uncertainty **$\pm 0.09 \times 10^{-6} \text{ V}/(\text{W}/\text{m}^2)$**

the number following the \pm symbol is the expanded uncertainty with a coverage factor $k = 2$, and defines an interval estimated to have a level of confidence of 95 percent

Product specifications and conformity

1:	ISO 9060 secondary standard	verified
2:	resistance	18.9 Ω
3:	insulation resistance	> 100 x 10⁶ Ω
4:	response time (95 %)	2.7 s
5:	temperature response	verified
6:	directional response	verified
7:	tilt measurement uncertainty	$\pm 1^\circ$ (0 to 90 $^\circ$)

Table 0.1 connections

PIN	WIRE	SR30
1	Brown	VDC [+]
4	Black	VDC [-]
3	Blue	not connected
2	White	RS-485 B / B' [+]
5	Grey	RS-485 A / A' [-]
	Yellow	shield

Calibration procedure according to ISO 9847. Traceability of calibration is to the WRR (World Radiometric Reference) maintained at the World Radiation Center in Davos, Switzerland.

Please consult the user manual for set up, operation and maintenance instructions, and information on measurement uncertainty during actual use.

Person authorising acceptance and release of product:
 L. Asaa

Date:
 24-05-2018

Directional response

 Pages: 5
 Release date: 24-05-2018

Product code	SR30-D1
Product identification	serial number 2489
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result

 Directional response **$\leq \pm 6.0 \text{ W/m}^2$**

Measurement process

Characterised parameter	dependence of sensitivity resulting from the direction of irradiance (a measure of the deviations from an ideal cosine response and its azimuthal variation)
Measurement functions	$C_{rel} = S(\theta)/(S(0) \cdot \cos(\theta) - 1) \cdot 100 \%$ with C_{rel} the deviation from an ideal cosine response at zenith angle θ in [%], $S(\theta)$ the sensitivity to beam irradiance at zenith angle θ in $[V/(W/m^2)]$, $S(0)$ the sensitivity to beam irradiance at normal incidence, θ the incoming angle from zenith in $[\circ]$ $C_{abs} = (S(\theta)/(S(0) \cdot \cos(\theta) - 1)) \cdot \cos(\theta) \cdot 1000$ with C_{abs} the directional response as defined below in $[W/m^2]$
Measurement equipment	Hukseflux Directional Response Characterisation

Conformity assessment

Definition of measurand	The directional response is the error caused by assuming that the reported sensitivity is valid when measuring from any direction a beam whose normal incidence is 1000 W/m^2
Acceptance interval	ISO 9060 specifies a limit on the directional response for a secondary standard pyranometer of $\pm 10 \text{ W/m}^2$
Conclusion	Conformity verified

Table 0.2 directional response test result

DIRECTIONAL RESPONSE TEST								
azimuth	North		East		South		West	
	C_{abs} [W/m ²]	C_{rel} [%]	C_{abs} [W/m ²]	C_{rel} [%]	C_{abs} [W/m ²]	C_{rel} [%]	C_{abs} [W/m ²]	C_{rel} [%]
zenith								
40 °	+6.0	+0.8	+2.5	+0.3	+1.0	+0.1	+4.4	+0.6
60 °	+4.7	+0.9	+1.7	+0.3	+1.4	+0.3	+4.8	+1.0
70 °	+3.3	+1.0	+0.9	+0.3	+1.8	+0.5	+3.8	+1.1
80 °	+3.0	+1.7	+2.3	+1.3	+4.7	+2.7	+5.1	+2.9

Person performing characterisation:

C. van der Ham

Date:

14-05-2018

Temperature response

 Pages: 5
 Release date: 24-05-2018

Product code **SR30-D1**
 Product identification **serial number 2489**
 Product type pyranometer
 Measurand hemispherical solar radiation
 Classification secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result

Temperature response **< ± 0.04 % (-30 to +50 °C)**
 Temperature coefficients*
a = -18.3206 x 10⁻⁶ °C⁻²
b = 7.2994 x 10⁻⁴ °C⁻¹
c = 0.9927

* These temperature coefficients are applied internally in the instrument

Measurement process

Characterised parameter dependence of sensitivity to ambient temperature
 Measurement function $S(T) = S_0 \cdot (a \cdot T^2 + b \cdot T + c)$
 with $S(T)$ sensitivity in [V/(W/m²)] at an instrument body temperature T , S_0 sensitivity at 20 °C instrument body temperature, T the instrument body temperature in [°C], a , b and c the temperature coefficients determined from a second order polynomial fit
 Measurement equipment Hukseflux Temperature Response Characterisation

Conformity assessment

Definition of measurand* Temperature response is the remaining percentage deviation in sensitivity due to change in ambient temperature within a temperature interval after the temperature coefficients are applied
 Temperature interval -30 to +50 °C
 Acceptance interval Hukseflux specifies a limit on the temperature response for a SR30-D1 of ± 0.4 %
 Conclusion Conformity verified

* This is an adaptation of the definition in ISO 9060, which specifies a limit on the temperature response for a secondary standard pyranometer of 2 % within a temperature interval of 50 K.

Table 0.3 temperature dependence test result

TEMPERATURE DEPENDENCE TEST					
T [°C]	-30	-10	10	30	50
remaining deviation	+0.02%	-0.04%	+0.01%	+0.03%	-0.02%

Person performing characterisation:

L. Asaa

Date:

09-05-2018

Tilt sensor characterisation

 Pages: 5
 Release date: 24-05-2018

Product code	SR30-D1
Product identification	serial number 2489
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Characterisation result*	x-axis	y-axis	z-axis
gain	0.9977	1.0082	1.0018
offset	-106	230	106
temperature coefficient a_0	-0.0109×10^{-12}	1.7312×10^{-12}	-0.0080×10^{-12}
temperature coefficient a_1	2.1632	-3.5266	-2.8833
temperature coefficient a_2	-0.0211×10^{-2}	-0.4875×10^{-2}	-0.8171×10^{-2}
temperature coefficient a_3	-0.4200×10^{-4}	0.3182×10^{-4}	-1.0408×10^{-4}

* These gains, offsets and temperature coefficients are applied internally in the instrument

Measurement process

Characterised parameters

Measurement equation

tilt sensor gains and offsets

$$\theta = 360/2\pi \cdot \text{atan}((x^2 + y^2)^{1/2}/z)$$

$$x, y, z = \text{gain}_{x,y,z} \cdot \text{raw}_{x,y,z} + \text{offset}_{x,y,z} + d_{x,y,z}(T)$$

$$d_{x,y,z}(T) = a_{0x,0y,0z} + a_{1x,1y,1z} \cdot T + a_{2x,2y,2z} \cdot T^2 + a_{3x,3y,3z} \cdot T^3$$

with θ the sensor tilt angle with respect to the horizontal in [°],
 atan the arctangent function, x, y and z the corrected accelerometer counts, $\text{gain}_{x,y,z}$ the tilt sensor gains, $\text{raw}_{x,y,z}$ the raw accelerometer counts, $\text{offset}_{x,y,z}$ the tilt sensor offsets, $d_{x,y,z}(T)$ the correction for temperature dependence of the tilt measurement at an instrument body temperature T, a_0 , a_1 , a_2 and a_3 the temperature coefficients determined from a third order polynomial fit. Labels x, y and z refer to the three accelerometer axes.

Measurement process

Alignment with the bubble level is attained in horizontal position by introducing gains and offsets.

Gains and offsets are determined in horizontal position and at a tilt angle of 90 °. Temperature dependence of the tilt measurement is determined at a tilt angle of 90 ° between -30 and + 50 °C.

Measurement method

Hukseflux Tilt Sensor Characterisation

Conformity assessment

Description of assessment

The tilt measurement uncertainty is verified in horizontal position and at a tilt angle of 90 °

Acceptance interval

The tilt measurement uncertainty is specified at $\pm 1^\circ$ (0 to 90 °)

Conclusion

Conformity verified

Person performing tilt sensor characterisation:

L. Asaa

Date:

22-05-2018