Hukseflux
Thermal Sensors

Hukseflux Thermal Sensors B.V.
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Calibration certificate

Pages: 5
Release date: 29-05-2018

Product code	**SR30-D1**
Product identification	**serial number 2488**
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)

Calibration result

Sensitivity	**$S = 9.32 \times 10^{-6}$ V/(W/m²)**
Calibration uncertainty	**$\pm 0.09 \times 10^{-6}$ V/(W/m²)**
	the number following the ± 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/m^2

Measurement process

Metrological characteristic	S in [$V/(W/m^2)$]: sensitivity to irradiance in the 300 to 3000 $\times 10^{-9}$ 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 ± 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	14.60×10^{-6} $V/(W/m^2)$
Uncertainty of standard	± 0.4 % expanded uncertainty with a coverage factor of 2
Uncertainty of correction	based on experience the expanded uncertainty is ± 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:
R. van Velzen

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the number following the ± 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	**21.2 Ω**
3:	insulation resistance	**> 100×10^{6} Ω**
4:	response time (95 %)	**2.7 s**
5:	temperature response	**verified**
6:	directional response	**verified**
7:	tilt measurement uncertainty	**± 1 ° (0 to 90 °)**

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:
H.E. Brouwer

Date:
29-05-2018

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Directional response

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Characterisation result

Directional response **≤ ± 6.8 W/m²**

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(θ) the sensitivity to beam irradiance at zenith angle θ in [V/(W/m²)], S(0) the sensitivity to beam irradiance at normal incidence, θ the incoming angle from zenith in [°]
$C_{abs} = (S(\theta)/(S(0)\cdot\cos(\theta) - 1))\cdot\cos(\theta)\cdot 1000$
with C_{abs} the directional response as defined below in [W/m²]

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/m²

Acceptance interval: ISO 9060 specifies a limit on the directional response for a secondary standard pyranometer of ± 10 W/m²

Conclusion: Conformity verified

Table 0.2 *directional response test result*

DIRECTIONAL RESPONSE TEST								
azimuth	North		East		South		West	
zenith	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]	C_{abs} [W/m²]	C_{rel} [%]
40 °	+5.2	+0.7	+4.8	+0.6	+2.1	+0.3	+3.3	+0.4
60 °	+4.4	+0.9	+5.4	+1.1	+3.7	+0.7	+3.3	+0.7
70 °	+2.7	+0.8	+5.1	+1.5	+4.7	+1.4	+2.4	+0.7
80 °	+1.6	+0.9	+6.1	+3.5	+6.8	+3.9	+3.0	+1.7

Person performing characterisation:
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Date:
26-05-2018

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Temperature response

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

Characterisation result

Temperature response	**< ± 0.07 % (-30 to +50 °C)**
Temperature coefficients*	**$a = -18.2852 \times 10^{-6}$ °C^{-2}**
	$b = 6.8304 \times 10^{-4}$ °C^{-1}
	$c = 0.9937$

* 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	+0.03%	-0.07%	0.00%	+0.06%	-0.03%

Person performing characterisation:
L. Asaa

Date:
26-05-2018

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Tilt sensor characterisation

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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	1.0257	0.9890	1.0099
offset	-220	-71	24
temperature coefficient a_0	2.7023×10^{-12}	-0.3648×10^{-12}	0.0071×10^{-12}
temperature coefficient a_1	-1.3207	-0.0305	1.4266
temperature coefficient a_2	-0.3194×10^{-2}	-0.4582×10^{-2}	-2.6626×10^{-2}
temperature coefficient a_3	0.4294×10^{-4}	0.9519×10^{-4}	-13.2442×10^{-4}

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

Measurement process

Characterised parameters: tilt sensor gains and offsets

Measurement equation:
$\theta = 360/2\pi \cdot \mathrm{atan}((x^2 + y^2)^{1/2}/z)$
$x,y,z = gain_{x,y,z} \cdot raw_{x,y,z} + offset_{x,y,z} + d_{x,y,z}(T)$
$d_{x,y,z}(T) = a_{0x,0y,0z} + a_{1x,1y,1z} \cdot T + a_{2x,2y,2z} \cdot T^2 + a_{3x,3y,3z} \cdot T^3$
with θ the sensor tilt angle with respect to the horizontal in [°], atan the arctangent function, x, y and z the corrected accelerometer counts, $gain_{x,y,z}$ the tilt sensor gains, $raw_{x,y,z}$ the raw accelerometer counts, $offset_{x,y,z}$ 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 ± 1° (0 to 90 °)

Conclusion: Conformity verified

Person performing tilt sensor characterisation:
L. Asaa

Date:
29-05-2018