Hukseflux
Thermal Sensors

SR20/SR20-D1 for PV system monitoring

SR20 secondary standard pyranometers: why PV system asset managers prefer a high-accuracy pyranometer with the right paperwork

SR20 is a solar radiation sensor of the highest category in the ISO 9060 classification system: secondary standard. SR20 pyranometer should be used where the highest measurement accuracy is required. SR20-D1 is the digital equivalent of the regular SR20 with analogue output. A unique feature of the SR20 series is that every instrument is individually tested and supplied with the right paperwork.

- Hukseflux secondary standard pyranometers offer the highest accuracy and are supplied with the right paperwork. High-accuracy measurement records of PV system performance increase the value of a PV plant by narrowing down risk profiles.
- A record of instrument performance according to the requirements of the GUM and ISO 9060 standards is essential as proof of instrument measurement accuracy. Only Hukseflux includes this.

Executive summary

Figure 1 *SR20 secondary standard pyranometer*

Figure 2 *accurate PV system performance monitoring*

Introduction

PV power plants are increasingly treated as a commercial investment. Traditionally system performance was monitored to allow operators to optimise system performance. Nowadays, in the process of monitoring and selecting measurement equipment, the investment-related considerations often dominate over operational aspects. For asset managers, high-accuracy measurements during PV system operation lead to a narrower specification of proven performance. This increases the value of the power plant, which is relevant in case the plant is financed with borrowed money or if it is sold. Accurate data allow investors to borrow a higher percentage of the total investment or borrow at a lower interest rate. This creates leverage; i.e. potentially multiplied financial gains.

Why it pays off to have improved measurement accuracy

The opportunity to get a better risk-rating justifies a higher investment in measurement equipment.

Why SR20 pyranometer

- The right paperwork: including certificates of temperature response and directional response
- Directional response at 4 azimuth angles
- Best in class calibration uncertainty
- Best in class temperature response (characterised up to + 50 °C, while competitors typically stop at + 40 °C)

What is the right paperwork, and why does it matter

The ISO/IEC Guide 99:2007 International Vocabulary of Metrology states that "type B evaluation of measurement uncertainty may be evaluated based on information obtained from the accuracy class of a verified measuring instrument" [1]. The ISO 9060:1990 standard, which covers pyranometer classification, demands for secondary standard pyranometers that "all specifications are tested for every individual instrument" [2]. In practice, the leading manufacturers of pyranometers test their secondary standard instruments, but not all supply these instruments with test certificates for the most critical specifications. These critical specifications are temperature dependence (this should be at least up to +50 °C for PV applications) and directional response (this should be up to 80 ° zenith angle in the extreme east and west directions for PV applications). Having the right certificates matters. By having these, you avoid any issues of liability.

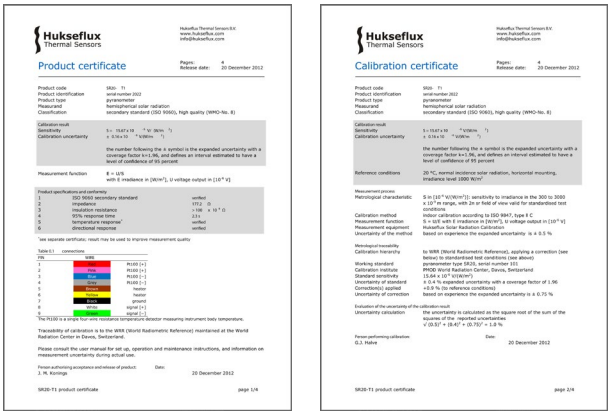
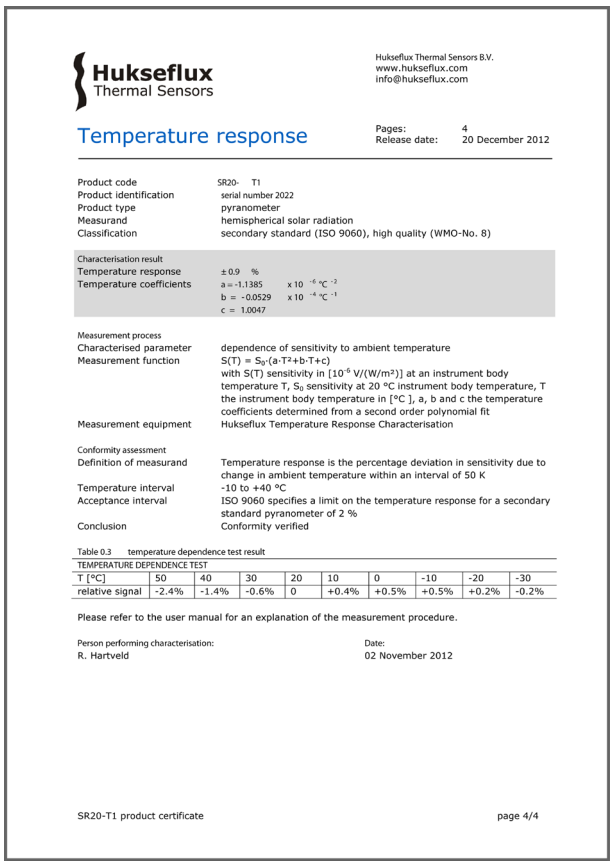


Figure 4 *Hukseflux product and calibration certificates*

Uncertainty evaluation

The uncertainty of a measurement under outdoor conditions depends on many factors. Guidelines for uncertainty evaluation according to the "Guide to Expression of Uncertainty in Measurement" (GUM) can be found in our manuals. We provide spreadsheets to assist in the process of uncertainty evaluation of your measurement.



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Temperature response

Pages: 4
Release date: 20 December 2012

Product code	SR20- T1
Product identification	serial number 2022
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)
Characterisation result	
Temperature response	± 0.9 %
Temperature coefficients	a = -1.1385 x 10 $^{-6}$ °C $^{-2}$
	b = -0.0529 x 10 $^{-4}$ °C $^{-1}$
	c = 1.0047
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 [10^{-6} 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 percentage deviation in sensitivity due to change in ambient temperature within an interval of 50 K
Temperature interval	-10 to +40 °C
Acceptance interval	ISO 9060 specifies a limit on the temperature response for a secondary standard pyranometer of 2 %
Conclusion	Conformity verified

Table 0.3 temperature dependence test result

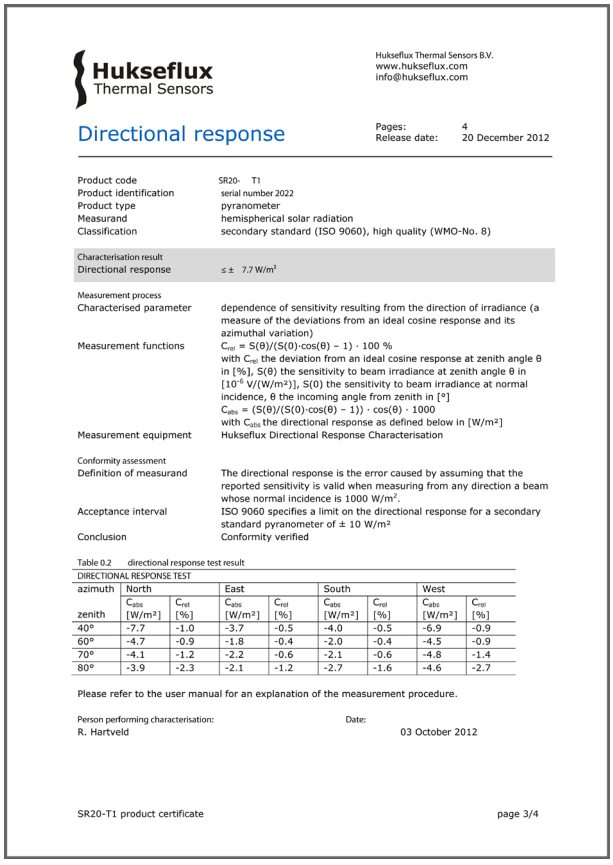
TEMPERATURE DEPENDENCE TEST									
T [°C]	50	40	30	20	10	0	-10	-20	-30
relative signal	-2.4%	-1.4%	-0.6%	0	+0.4%	+0.5%	+0.5%	+0.2%	-0.2%

Please refer to the user manual for an explanation of the measurement procedure.

Person performing characterisation: R. Hartveld
Date: 02 November 2012

SR20-T1 product certificate page 4/4

Figure 3 *The right paperwork. Test certificate of temperature response supplied with every individual instrument*



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Directional response

Pages: 4
Release date: 20 December 2012

Product code	SR20- T1
Product identification	serial number 2022
Product type	pyranometer
Measurand	hemispherical solar radiation
Classification	secondary standard (ISO 9060), high quality (WMO-No. 8)
Characterisation result	
Directional response	≤ ± 7.7 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 [10^{-6} 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°	-7.7	-1.0	-3.7	-0.5	-4.0	-0.5	-6.9	-0.9
60°	-4.7	-0.9	-1.8	-0.4	-2.0	-0.4	-4.5	-0.9
70°	-4.1	-1.2	-2.2	-0.6	-2.1	-0.6	-4.8	-1.4
80°	-3.9	-2.3	-2.1	-1.2	-2.7	-1.6	-4.6	-2.7

Please refer to the user manual for an explanation of the measurement procedure.

Person performing characterisation: R. Hartveld
Date: 03 October 2012

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Figure 5 *The right paperwork. Test certificate of directional response supplied with every individual instrument*

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Standards

Applicable instrument classification standards are ISO 9060 and WMO-No. 8. Calibration is according to ISO 9847. PV related standards are ASTM E2848 and IEC 61724.

Demanding applications

SR20's low temperature dependence makes it an ideal candidate for use under very cold and very hot conditions. The temperature dependence of every individual instrument is tested and supplied as a second degree polynomial. This information can be used for further reduction of temperature dependence during post-processing.

Figure 6 *SR20 pyranometer side view*

See also

- SR20 secondary standard pyranometer – analogue output
- SR20-D1 digital secondary standard pyranometer – Modbus protocol
- SR20-TR secondary standard pyranometer with 4-20 mA transmitter
- VU01 ventilation unit for ventilated SR20 / SR20-D1 pyranometer measurements
- alternative instruments: SR11 and SR05 for lower accuracy measurements
- SR12 first class pyranometer for solar energy testing applications
- the making of SR20 documented
- view our complete product range of solar sensors

SR20 specifications

Measurand	hemispherical solar radiation
ISO classification	secondary standard pyranometer
Calibration uncertainty	< 1.2 % (k = 2)
Calibration traceability	to WRR
Rated operating temperature range	-40 to +80 °C
Temperature response test of individual instrument	report included, with second degree polynomial from -30 to +50 °C
Directional response test of individual instrument	report included, with measurements at all 4 azimuth angles up to 80 ° zenith angle
Temperature response	
SR20	<± 1 % (-10 to +40 °C) <± 0.4 % (-30 to +50 °C) with correction in dataprocessing
SR20-D1	<± 0.4 % (-30 to +50 °C)

About Hukseflux

Hukseflux Thermal Sensors makes sensors and measuring systems. We also provide services: calibration and material characterisation. Our main area of expertise is measurement of heat transfer and thermal quantities such as solar radiation, heat flux and thermal conductivity. Hukseflux is ISO 9001 certified. Hukseflux products and services are offered worldwide via our office in Delft, the Netherlands and local distributors.

Referenced documents

[1] ISO, (2007), ISO/IEC Guide 99:2007 International Vocabulary of Metrology – Basic and general concepts and associated terms (VIM), published by ISO, www.iso.org

[2] ISO, (1990), ISO 9060:1990 Solar energy – Specification and classification of instruments for measuring hemispherical solar and direct solar radiation, published by ISO, www.iso.org

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