


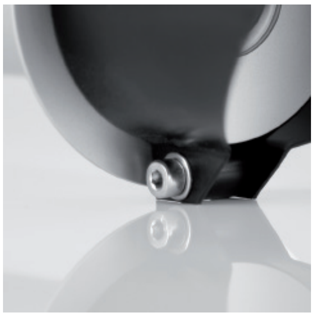

Instruction Manual

SHP1 • Smart Pyrheliometer

Important user information

Dear customer, thank you for purchasing a Kipp & Zonen instrument. It is essential that you read this manual completely for a full understanding of the proper and safe installation, use, maintenance and operation of your new SHP1 pyrheliometer.

We understand that no instruction manual is perfect, so should you have any comments regarding this manual we will be pleased to receive them at:

Kipp & Zonen B.V.
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P.O. Box 507, 2600 AM Delft,
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Warranty and liability

Kipp & Zonen guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Kipp & Zonen.

Kipp & Zonen shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of business opportunities, loss of use and other related exposures, however incurred, rising from the faulty and incorrect use of the product.

Modifications made by the user may affect the instrument performance, void the warranty, or affect the validity of the CE declaration or other approvals and compliances to applicable International Standards.

Kipp & Zonen reserves the right to make changes to this manual, brochures, specifications and other product documentation without prior notice.

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KIPP & ZONEN
SINCE 1830

Declaration of Conformity

Kipp & Zonen B.V.
Delftechpark 36, 2628 XH Delft
P.O. Box 507, 2600 AM Delft
The Netherlands

declares under our sole responsibility that the product

SHP1 Smart Pyrheliometer

to which this declaration relates, is in conformity with European Harmonised Standards as published in the Official Journal of the EC, based on the following standard

[EMC - Emissions]	**EN 61326-2-1:2013** and **EN 61326-2-3:2013**
[EMC - Immunity]	**EN 61326-2-1:2013** and **EN 61326-2-3:2013**
[Environmental Affairs]	**EN 50581:2012**

following the provisions

EMC-directive	**2014/30/EC**
RoHS Directive	**2011/65/EC**

also, this device complies to
[EMC - FCC] **Title 47CFR part 15**

Delft, 7 February 2017

E. Valks - CEO
Kipp & Zonen B.V.

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1. Introduction

Throughout this manual the following symbols are used to indicate to the user important information.

General warning about conditions, other than those caused by high voltage electricity, which may result in physical injury and/or damage to the equipment or cause the equipment to not operate correctly.

Note Useful information for the user

1.1 Product overview

According to International Standard ISO 9060:1990 and the World Meteorological Organization (WMO) a pyrheliometer is the designated type of instrument for the measurement of direct solar radiation. The SHP1 pyrheliometer is compliant with the "First Class" class specified by the international standards.

This manual, together with the instruction sheet, provides information related to the installation, maintenance, calibration, product specifications and applications of the SHP1 pyrheliometer.

If any questions should remain, please contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: **support@kippzonen.com**

Please go to **www.kippzonen.com** for information about other Kipp & Zonen products, or to check for any updates to this manual or software.

1.1.1 The SHP1 pyrheliometer

SHP1 pyrheliometer is a high quality radiometer designed for measuring direct short-wave irradiance (radiant flux, W/m^2) which results from the radiant flux from a solid angle of 5 degrees.

SHP1 pyrheliometer features internal digital signal processing and interfaces optimised for industrial data acquisition and control systems. Kipp & Zonen has developed a smart interface that features RS-485 Modbus® data communication for connection to programmable logic controllers (PLC's), inverters, digital control equipment and the latest generation of data loggers. Amplified Voltage or Current outputs are also included for devices that have high-level analogue inputs or current loop interfaces.

The SHP1 is available in two versions. The SHP1-V has an analogue voltage output of 0 to 1 V, the SHP1-A has an analogue current output of 4 to 20 mA. Both have a 2-wire RS-485 interface with Modbus® (RTU) protocol. Both versions have minimised power consumption and are protected against short circuit and reversed polarity. The digital signal processing provides faster response times and, with an integrated temperature sensor, individual corrections for the temperature dependence of the detector are made.

To achieve the required spectral characteristics SHP1 uses a quartz window and thermopile detector. The waterproof connectors have gold-plated contacts.

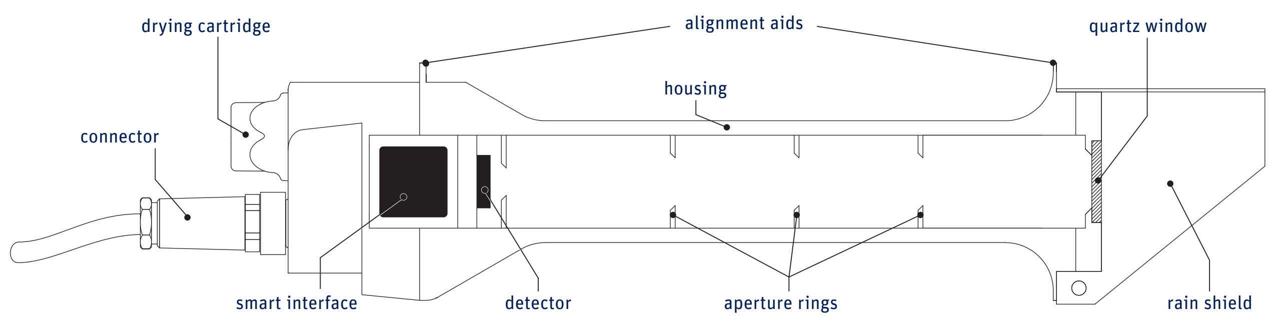
The pyrheliometer is normally delivered with a waterproof plug pre-wired to a high quality signal cable, typically this is 10 m long but other lengths are available. The instruments can also be ordered with a plug only, for the user to fit their own cable.

1.1.2 International Standard

For the SHP1 Second Class pyrheliometer ISO standard ISO 9060 applies.

Fully compliant with all ISO 9060:1990 specification criteria for an ISO Second Class pyrheliometer, the SHP1 features a thermocouple sensing element. An integrated temperature sensor with active and individual measured temperature compensation is included for improved temperature dependence of sensitivity.

1.2 Key parts of the SHP1 pyrheliometer



2. Installation

Please follow the instructions in this section carefully for the mechanical and electrical installation of the SHP1 pyrheliometer.

Do not turn on power to the instrument until instructed to do so.

Note Do not connect the instrument to a computer until instructed to do so.

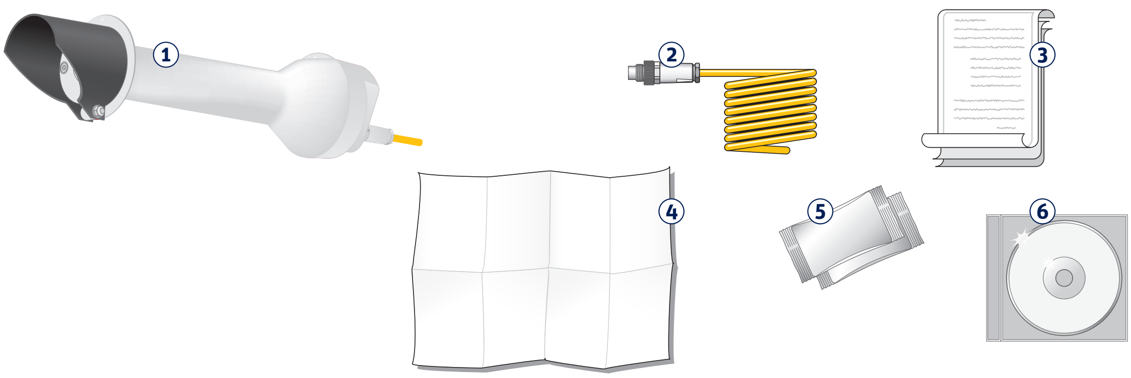
Note Do not turn on power to the operating computer until instructed to do so.

2.1 Included with the product

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport. If there is damage, a claim should be filed with the carrier immediately. In the case of damage and/or the contents are incomplete, contact your local Kipp & Zonen representative or e-mail the Kipp & Zonen customer and product support department at: **support@kippzonen.com**

Although a SHP1 pyheliometer is weather-proof and suitable for use in harsh environmental conditions, it has some delicate mechanical parts. Please keep the original packaging for safe transport of the radiometer to the measurement site, or for use when returning the radiometer for calibration.

The following items are included with a SHP1 pyrheliometer:
① Smart pyrheliometer and rain shield
② Cable, pre-wired with 8-pins connector or connector only for customer cable
③ Calibration certificate
④ Instruction sheet
⑤ 2 Dessicant bags
⑥ CD with product documentation and software



2.2 Tools required

The tool required to mount a SHP1 on a SOLYS 2 or 2AP sun tracker is a 3 mm Allen key. Normally, the drying cartridge for the SHP1 should be hand-tight, but a 16 mm or 5/8” open-ended wrench / spanner can be used to loosen it.

Check the condition of the desiccant in the SHP1 and replace before installation, if necessary; for example after a long storage period.

The SHP1 instruction sheet plus the sun tracker manual contain all information to do the installation. When using the digital output it might be convenient to set the Modbus® address prior to visiting the site, otherwise a computer and RS-485 / USB converter may be required during installation.

2.3 Location and support

The following steps must be carefully taken for optimal performance of the instrument.

2.3.1 Location

Ideally, the site for the pyrheliometer plus sun tracker should be free from any obstructions to the hemispherical view from the plane of the detector. If this is not possible, the site should be chosen in such a way that any obstruction over the azimuth range between earliest sunrise and latest sunset should have an elevation not exceeding 5° (the apparent sun diameter is 0.5°). Further details for installation of the sun tracker can be found in the manual of the used tracker.

It is evident that the radiometer should be located in such a way that a shadow will not be cast upon it at any time (for example by masts or ventilation ducts). Note that hot exhaust gas (> 100 °C) will produce some radiation in the spectral range of the radiometer and cause an offset in the measurements. This is important for an accurate measurement of the direct solar radiation.

The radiometer should be readily accessible for cleaning the front window and inspecting the desiccant.

2.3.2 Mounting

The mounting of the SHP1 pyrheliometer is related to the used sun tracker. Therefore we refer to the sun tracker manual for further instructions on how to mount the SHP1 on the side mounting plate of the sun tracker.

2.3.3 Fitting the connector and cable

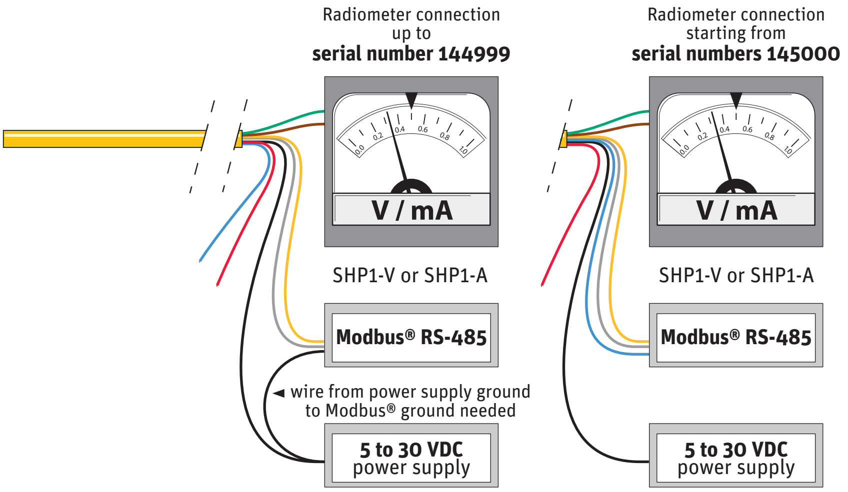
Locate the plug correctly in the radiometer socket, it only fits one way, and push it in. Screw the plug locking ring hand-tight. Over-tightening may damage the waterproof seal. Secure the cable so that it cannot blow in the wind or cause a shadow on the instrument.

Note The cable should be arranged with a curve below the instrument so that water drips off, rather than running along the cable up to the connector.

2.4 Electrical connections

As standard SHP1 pyrheliometers are supplied with a waterproof connector pre-wired to 10 m of high quality yellow cable with 8 wires and a shield covered with a black sleeve. Longer cables are available as options. The colour code of the wires and the connector pin numbers are shown below and on the instruction sheet.

Special attention is needed to prevent power or ground loops when connecting the SHP1 to multiple readout devices. Connecting the RS-485 to a grounded circuit and the analogue output to a floating circuit can cause unacceptable ground loops. This may cause differential voltages outside the SHP1 specifications and will damage the unit. We recommend using either the analogue or the digital output but not both. The maximum differential between either of the Modbus® RS-485 lines (yellow and grey) and the power ground / RS-485 common line (black) is 70 VDC.



Radiometer Connection		
Wire	Function	Connect with
3 Green	Analogue out	V+/4-20 mA(+)
6 Brown	Analogue ground	V−/4-20 mA(−)
4 Yellow	Modbus® RS-485	B/B'/+
5 Grey	Modbus® RS-485	A/A'/−
7 White	Power 5 to 30 VDC (12 V recommended)	
8 Black	Power ground / RS-485 Common	
1 Red	None	Not connected
2 Blue	Modbus® common / Ground ⚠	
Shield	Housing	Ground *

* Connect to ground if radiometer not grounded

⚠ The blue wire is not connect with radiometers with serial number up to 144999

First connect all wires before plugging into the radiometer

The shield of the cable is connected to the aluminium radiometer housing through the connector body. The shield at the cable end may be connected to ground at the readout equipment. Lightning can induce high voltages in the shield but these will be led off at the pyrheliometer and data logger.

Note Long cables may be used, but the cable resistance must be smaller than 0.1% of the impedance of the readout equipment for the analogue outputs and may affect the baud rate of the RS-485 digital connection.

2.5 Power connection

The minimum power supply voltage for a SHP1 pyrheliometer is 5 VDC. However, for optimal performance it is advised to use 12 VDC, especially when long cables are used. 5-volt power can only be used in combination with a short cable, maximum 10 m.

It is advised to protect the output of the power supply with a fast blowing fuse of maximum 250 mA rating.

Typical power consumption SHP1-V		
5 VDC	max. 50 mW	(approx. 10.0 mA)
12 VDC	max. 55 mW	(approx. 4.5 mA)
24 VDC	max. 60 mW	(approx. 2.5 mA)

Maximum power consumption and input current.
65 mW and 2 mA at the highest input voltage.
63 mW and 12.5 mA at the lowest input voltage.
The maximum inrush current is 200 mA.

Typical power consumption SHP1-A		
5 VDC	77 mW	(approx. 28 mA with 100 Ω load resistor)
12 VDC	83 mW	(approx. 24 mA with 100 Ω load resistor)
24 VDC	100 mW	(approx. 6 mA with 100 Ω load resistor)

The above mW values represent the dissipation within the SHP1-A. For the total power the energy in the load resistor has to be added.

For supply voltages below 12 Volts or above 20 Volts it is advised to use a load resistor of less than 500 Ω to keep the power consumption as low as possible.

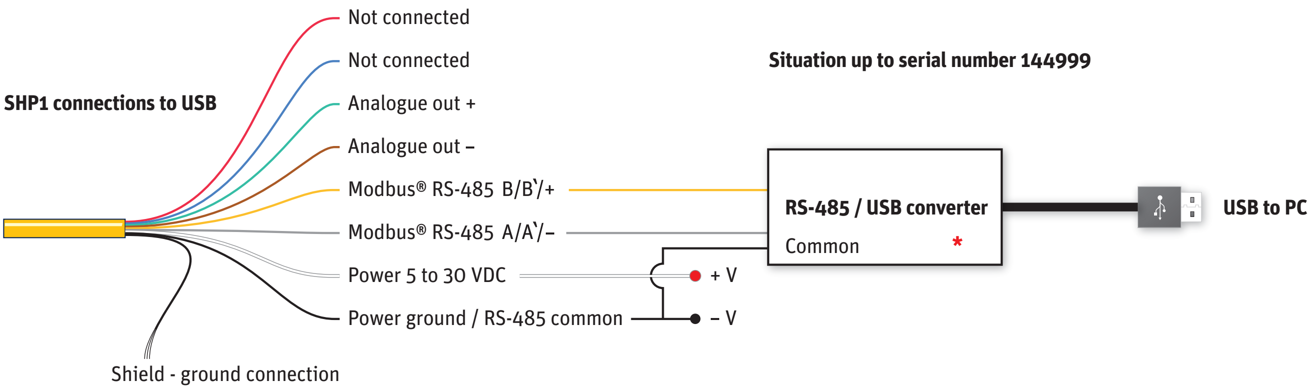
2.6 Data connection

Connection to a Personal Computer by Universal Serial Bus (USB)

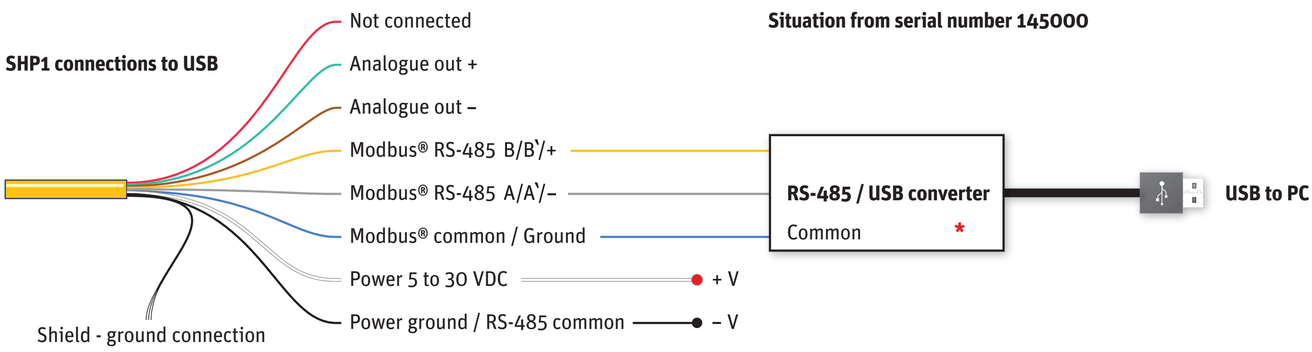
The connection depends on the use of a RS-485 to USB converter.

The converter **must** have galvanic isolation between the inputs and outputs to prevent possible damage to the SHP1 digital interface. This is particularly an issue with portable computers (laptops, etc.) in which the power supplies can generate large voltage spikes.

A suitable converter is the model USOPTL4 from B & B Electronics. One end has the USB connector to the PC the other end has a connector with screw terminals for the instrument wires. This RS-485 converter is powered from the USB interface, so no additional power adaptor is necessary.



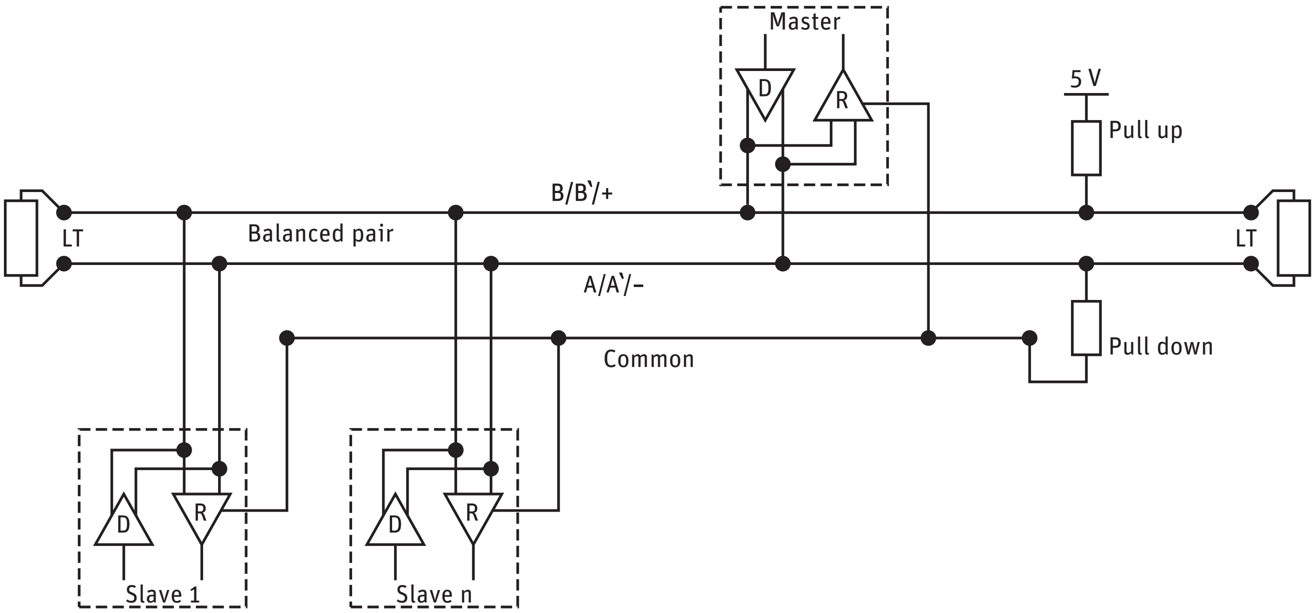
***Note** Switches on the converter should be set for RS-485, 2-wire operation and Echo off.



***Note** Switches on the converter should be set for RS-485, 2-wire operation and Echo off.

Connection to a RS-485 Network

The digital interface can be connected to a 2-wire RS-485 network as shown below.



The interface needs also an external power to provide the voltage for the electronics. If the interface is the last device on the network then a terminator consisting of a 120 Ω or 150 Ω resistor has to be connected between terminal A/A'/- and B/B'/+. Never place the line termination on the derivation cable. It is required to install the pull up and pull down resistors as shown in the previous figure. The value of these resistors has to be within 650 Ω and 850 Ω.

2.7 Analogue output connection

The SHP1-V (Volt version) has been factory set to an output of -200 to 2000 W/m². This applies only to the analogue output and means that an output of 0 Volt corresponds to -200 W/m² (this will never be reached) and 1 Volt corresponds to 2000 W/m².

The digital output range can be modified with Modbus® commands. For the SHP1 the output range can be set to -200 to 4000 W/m² for 0 to 1 Volt.

The range has to start negative in order to show (small) negative readings also the analogue output itself cannot go negative. If used in atmospheric conditions it is advised to keep the range as factory set.

The same applies for the SHP1-A (current version) that has been factory set to 0 to 1600 W/m² for 4 to 20 mA.

Here negative inputs will make the output go under 4 mA.

2.8 Calculations

2.8.1 Calculation 0 to 1 Volt version

The output is defined from 0 to 1 Volt representing -200 to 2000 W/m².

The irradiance value ($E_{\downarrow solar}$) can be simply calculated as shown below in *formula 1*. The formula assumes the factory default setting of the analogue output. For calculation of the solar irradiance (global or reflected) the following formula must be applied:

formula 1

$$E_{\downarrow solar} = (V \times 2200) - 200$$

$E_{\downarrow solar}$ = Solar radiation [W/m²]
V = Output of radiometer [Volt]

2.8.2 Calculation 4 to 20 mA version

The output is defined from 4 to 20 mA representing 0 to 1600 W/m².

Negative outputs can cause the output to go slightly below 4 mA.

The irradiance value ($E_{\downarrow solar}$) can be simply calculated as shown below in *formula 2*. The formula assumes the factory default setting of the analogue output. For calculation of the solar irradiance (global or reflected) the following formula must be applied:

formula 2

$$E_{\downarrow solar} = (mA - 4) \times 100$$

$E_{\downarrow solar}$ = Solar radiation [W/m²]
mA = Output of radiometer [mA]

2.8.3 Recommended cable types

Where cables need to be extended, or the customer prefers to provide their own cables, they should be suitable for outdoor used and UV resistant.

Recommended types	
RS-485	Ethernet CAT 5 shielded twisted pair (STP)
0 to 1 V	Shielded 2-core signal cable
4 to 20 mA	Shielded twisted pair control cable

3. Accessories

Below is a brief description of the available cables for the SHP1 pyrheliometer.

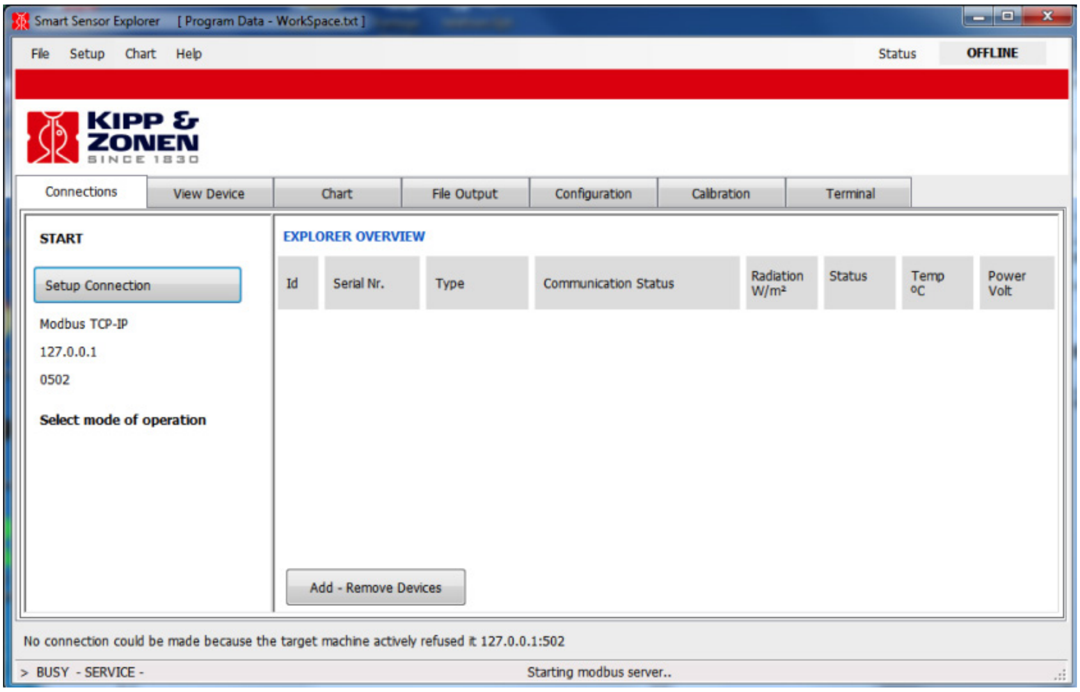
3.1 Cables

For connection, a standard 10 m cable (8 wires) is supplied with a straight 8 pin connector on one side and loose ends on the other side. Optional longer cables are available or just a loose connector to make your own cable / connection.

25 m cable with connector
50 m cable with connector
100 m cable with connector
Loose connector without cable

4. SmartExplorer software and Modbus® communication

The SmartExplorer software allows you to configure a smart sensor and to collect real-time data. SmartExplorer runs on a PC with Windows Vista, 7 or 8 and when installing downloads the .NET 4.5 frame work from the Microsoft Server. When using the software on site, make sure the software is already installed on your laptop.



To connect a smart radiometer to a PC, a RS-485 to USB converter is required. Recommended is using an isolated version like the 'USOPTL4' from B&B for safety and protection of the PC.

- Configuration makes it possible to configure a smart sensor 'out of the box' and test the smart sensor before the sensor is used in an operational network.
- The SmartExplorer software can use a RS-485 to USB or Ethernet interface to connect to a PC
- Collecting data makes it possible to store data from the smart sensor in a comma separated file. The comma separated file is created at the beginning of every new day or at the beginning of the first day of the week.
- The SmartExplorer software can also be used to monitor and/or log up to 10 instruments simultaneously and works with all smart radiometers (SMP, SHP, SGR, SUV)

Please check the separate SmartExplorer manual for detailed information about the set-up, monitoring and data logging of the smart sensors. The latest version of the manual can be downloaded the from the relevant product page under the tab 'Download' from our website.

The factory default communication parameters for all Smarts are:
- The factory default Baud rate of a smart sensor is '19200 baud'
- The factory default Size and Parity is '8 bits - even - 1 stopbit'
- The factory default Modbus® address is 1

5. Operation and measurement

SHP1 pyrheliometers only require suitable sources of power and radiation (light) to operate and make measurements. However, it is necessary to connect them to some sort of readout or data storage device in order to save the measurements, there is no internal data memory.

5.1 Data collection

An optimal setting for the data interval is to sample every second and store one minute averages. For setting up the combination of pyrheliometer and data storage please refer to the manual of the data collection device.

Take care when using the analogue output to match the output range of the pyrheliometer closely to the input range of the data collection device to maximise the available resolution and minimise noise.

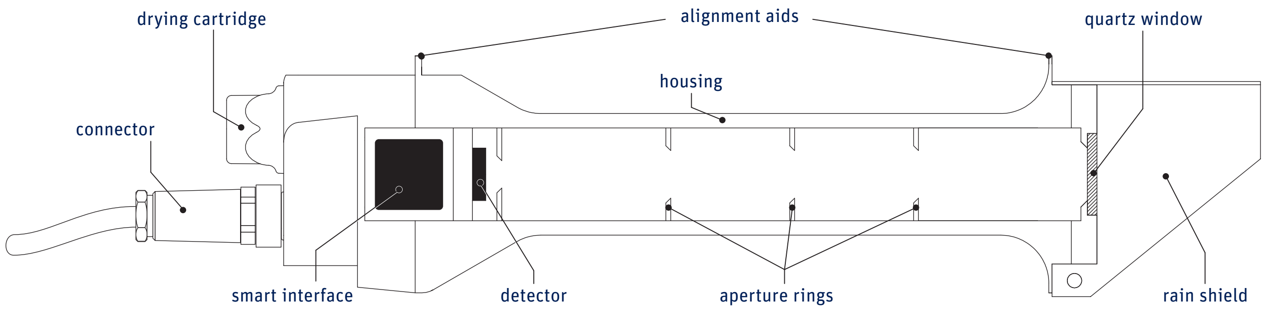
This can be done by determining the maximum expected analogue output of the pyrheliometer in your application and taking the minimum input range of your data collection device that can just handle that signal.

5.2 Key parts of SHP1 pyrheliometer

The detector of the SHP1 is based on passive thermal sensing element called a thermopile. Although the detector construction differs between models, the fundamental working principle is applicable to all radiometers.

The thermopile responds to the total energy absorbed by a unique black surface coating developed by Kipp & Zonen, which is non-spectrally selective. The thermopile warms up and the heat generated flows through a thermal resistance to a heat-sink, the pyrheliometer housing. The temperature difference across the thermal resistance of the detector is converted into a small voltage as a linear function of the absorbed irradiance.

A drying cartridge in the SHP1 pyrheliometer housing is filled with replaceable silica gel and prevents condensation on the inner side of the window, which can cool down considerably on clear windless nights.



5.2.1 Window

The material of the pyrheliometer window defines the spectral measurement range of the instrument. In general 99% of the solar radiation spectrum will be transmitted through the window and will be absorbed by the detector. The SHP1 window is made of quartz.

5.2.2 Detector

The thermopile sensing element is made up of a large number of thermocouple junction pairs connected electrically in series. The absorption of thermal radiation by one of the thermocouple junctions, called the active (or 'hot') junction, increases its temperature. The differential temperature between the active junction and a reference ('cold') junction kept at a fixed temperature produces an electromotive force directly proportional to the differential temperature created.

This is a thermoelectric effect. The sensitivity of a pyrheliometer depends on the individual physical properties of the thermopile and its construction. The sensitivity of each thermopile is unique and therefore each radiometer has an individual calibration factor. This sensitivity is stored in the SHP1 pyrheliometer configuration memory.

The unique black coating on the top surface of the thermopile has a rough structure that effectively 'traps' more than 97 % of the incident radiation and heats up the hot junctions. The black-coated thermopile forms the detector, which has a spectral selectivity of less than 2 %. This means that within the spectral range of the pyrheliometer, the absorption for each wavelength is equal to within 2 %. The black absorptive coating is one of the most crucial and delicate parts of the pyrheliometer, Kipp & Zonen's provides the best possible stability over a long period of time under all meteorological circumstances.

5.2.3 Housing

The radiometer housing accommodates all the key parts of a SHP1 pyrheliometer. The anodized aluminium parts are lightweight and give high mechanical and thermal stability to the instrument.

Due to fine mechanical construction SHP1 pyrheliometers are virtually sealed and comply with international standard IP 67.

5.2.4 Drying cartridge

To keep the detector and electronics dry and to prevent condensation forming inside the window with temperature changes a self-indicating silica gel desiccant is used to absorb humidity within the pyrheliometer. When fresh the desiccant has an orange colour. After some time absorbing moisture the colour will change to clear (transparent). At this time the silica gel is not fully saturated, but should be replaced with fresh orange desiccant as soon as possible. Replacement desiccant is available through Kipp & Zonen representatives.

5.2.5 Cable and connector

For ease of installation and replacement during re-calibration of the radiometer, the SHP1 is provided with a waterproof cable socket fitted to the pyrheliometer housing. The matching waterproof plug is normally supplied pre-wired to a very high quality yellow cable selected for low noise, very wide temperature range and UV resistance.

Cables come pre-wired to the connector plug in a range of lengths, 10 m is standard. 25 m, 50 m and 100 m lengths are also available. The connector plug can also be supplied loose for the user to fit to their own cable.

6. Maintenance and re-calibration

SHP1 pyrheliometers are simple to maintain and do not require any special tools or training. There are no service items requiring scheduled replacement, only the desiccant of the SHP1 requires changing when needed, and a periodical check of the alignment at the sun.

6.1 Daily maintenance

Once installed, the radiometer needs little maintenance. The front window must be cleaned and inspected regularly.

The frequency of cleaning is highly dependent upon the local weather and environmental conditions, such as dust, airborne pollutants or salt spray in marine environments. Ideally, the window of the pyrheliometer should be cleaned every morning before sunrise.

Note Clean the window using pure alcohol or distilled water and a lint-free cloth. Ensure that no smears or deposits are left on the window.

6.2 Monthly maintenance

Check the desiccant in the drying cartridge. This is a self-indicating silica-gel. When it requires replacement the colour changes from orange to clear.

To replace the desiccant unscrew the cartridge from the radiometer housing, if it is tight a 16 mm or 5/8" open-ended wrench / spanner can be used to loosen it. Remove the cap from the end of the cartridge and safely dispose of the used silica-gel. Refill with fresh desiccant, and refit the end cap to the cartridge. Make sure that the o-ring seal and its seat in the housing are clean, grease with Vaseline if it is dry.

Note Screw in the drying cartridge hand-tight only, to avoid distorting the o-ring seal.

Desiccant refill packs are available from Kipp & Zonen. One pack is sufficient for one complete refill.

6.3 Yearly maintenance

Check all the electrical connections. Unscrew the plugs, clean if necessary and then reconnect.
Check cables for damage caused by accident or by rodents.
Check the instrument mountings and any supports are secure.

6.4 Calibration

An ideal radiometer gives an output that is proportional to the absolute irradiance level. This relationship can be expressed as a constant ratio called ‘sensitivity’. SHP1 pyrheliometers are very stable instruments, but they do change very slightly with time. This is largely due to exposure of the black detector coating to UV solar radiation. Re-calibration is recommended every two years. Normally this is carried out at the Kipp & Zonen factory or at an authorised calibration facility.

6.4.1 Calibration principle

At the Kipp & Zonen factory pyrheliometers are calibrated, or re-calibrated, in our laboratory according to ISO 9059:1990 ‘Solar energy - Calibration of field pyrheliometers by comparison to a reference pyrheliometer’.

Kipp & Zonen uses a Xenon lamp with precise voltage stabilisation. The irradiance at the radiometers is approximately 800 W/m².

The reference pyrheliometers are regularly calibrated outdoors at the World Radiation Centre (WRC) in Davos, Switzerland. The spectral content of the laboratory calibration lamp differs from the outdoor solar spectrum at the World Radiation Centre. However, this has no consequences for the transfer of calibration, because the reference and test radiometers have the same characteristics.

The sensitivity of the test pyrheliometer is calculated by comparison to the reference pyrheliometer readings and the calibration certificate is produced. At Kipp & Zonen the complete process is automated under computer control, including programming the SHP1 pyrheliometer with the correct calibration factors and default output range settings.

6.4.2 Calibration traceability to the WRR

Our reference pyrheliometers are calibrated at the World Radiation Centre (WRC) in Davos, Switzerland by comparison to the World Radiometric Reference (WRR). They are also fully characterized for linearity, temperature dependence and directional response to enable transfer of the sensitivity under the measurement conditions in Davos to our calibration laboratory conditions.

Kipp & Zonen keeps at least two reference instruments for each pyrheliometer model. These reference instruments are sent alternate years to the WRC for calibration, so that production and calibration in Delft can carry on without interruption.

Kipp & Zonen calibration certificates include an overview of the calibration method, details of the reference pyrheliometer used, traceability to the WRR, and the uncertainty in the full calibration chain from the WRR to the pyrheliometer being calibrated.

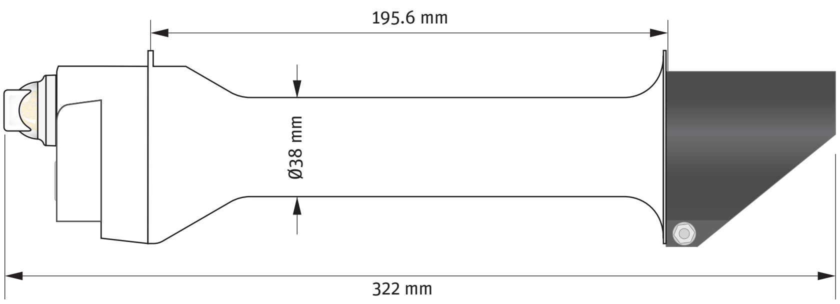
7. Specifications

Kipp & Zonen reserves the right to make changes to specifications and other product documentation without prior notice.

7.1 Optical and electrical

Specifications	SHP1
ISO 9060:1990 CLASSIFICATION	First Class
Response time (63 %)	< 0.7 s
Response time (95 %)	< 2 s
Zero offsets, temperature change (5 K/hr)	< 1 W/m²
Non-stability (change/year)	< 0.5 %
Non-linearity (0 to 1000 W/m²)	< 0.2 %
Temperature dependence of sensitivity	< 1 % (-40 °C to +70 °C) < 0.5 % (-30 °C to +60 °C)
Full viewing angle	5 ° (±0.2)
Slope angle	1 ° (±0.2)
Maximum irradiance	4000 W/m² (damage may occur above this level)
Operating temperature	-40 °C to +80 °C
Humidity (relative humidity)	0 to 100 % rH
Spectral range (50 % points)	200 to 4000 nm
Required sun tracker accuracy	< 0.5° from ideal
Weight	0.9 kg
Other specifications	
Analogue output	-V version: 0 to 1 V -A version: 4 to 20 mA
Analogue output range	-V version: -200 to 2000 W/m² (1) -A version: 0 to 1600 W/m²
Digital output	2-wire RS-485
Digital output maximum range	-400 to 4000 W/m²
Digital communication protocol	Modbus®
Operating temperature	-40 °C to +80 °C
Ingress Protection (IP)	67
Supply voltage	5 to 30 VDC
Power consumption (at 12 VDC)	-V version: 55 mW -A version: 100 mW
Expected daily uncertainty	< 1 %
Documentation	Calibration certificate traceable to WRR, multi-language instruction sheet, manual and software on CD-ROM
Recommended applications	High performance direct radiation monitoring for meteorological stations or concentrated solar energy applications
(1) The analogue output range of SHP1 can be rescaled by the user to a maximum of -200 to 4000 W/m²	
SHP1 pyrheliometer has a standard cable length of 10 m. Optional cable lengths 25 m, 50 m and 100 m	
Note: The performance specifications quoted are worst-case and/or maximum values	

7.2 Dimensions



8. Trouble shooting

There are no user-serviceable parts within the SHP1 pyrheliometer and it must not be opened without the agreement and instruction of Kipp & Zonen.

8.1 Output signal not present or incorrect

The following contains a procedure for checking the instrument in case it appears that it does not function correctly:

1. Check the SHP1 pyrheliometer cable wires are properly connected to the readout equipment.
2. Check the power supply (12 VDC recommended).
3. Check that the instrument has a unique Modbus® address.
4. Compare the digital and analogue outputs to see if the problem is in one output only.
5. Check the instrument location. Are there any obstructions that cast a shadow on the instrument by blocking the direct sun during some part of the day?
6. Check the window, it should be clear and clean. If condensation is deposited on the inside, please change the desiccant. If too much water is deposited internally the drying cartridge should be removed and the instrument warmed to dry it and then replace with new desiccant. It may take several days for the sensitivity to fully recover to the original value.
7. For analogue outputs check the data logger or integrator input offset such that a signal of 0 Volt or 4 mA (as appropriate) gives a ‘zero’ reading.
8. If water, frost or ice is deposited on the window, clean it. Probably water droplets will evaporate in less than one hour under sunlight.

Any malfunction or visible damage should be reported to your Kipp & Zonen representative, who will suggest the appropriate action.

8.2 Frequently Asked Questions

The most frequently asked questions are listed below. For an update or further information refer to our website at **www.kippzonen.com**

Q: Is it possible that direct radiation is higher than global radiation?

A: Yes, this is possible because the relation is:

Global = Diffuse + (Direct x cos α); α is the solar zenith angle

So with low solar elevation (small cos α) the contribution of the direct radiation to the total (global) is relatively small.

Q: When is the pyrheliometer properly aligned?

A: When the second alignment aid on top of the SHP1 is in the light spot falling through the first alignment aid the pyrheliometer is properly aligned. As long as the second alignment aid is in the light spot, the SHP1 is within specifications.

Q: Is the pyrheliometer calibration affected by the length of the signal cable?

A: With longer cable lengths the impedance increases, however it does not affect the radiometer sensitivity for the following reason. For the SHP1-V the impedance of the voltage measurement device is at least 1000 times more than the impedance of the pyrheliometer plus cable. Therefore the current that goes through the readout cable is negligible and won’t generate an offset.

For the SHP1-A current versions the cable length is limited by the power supply voltage and voltage drop over the cable. However the low cable impedance (80 Ω/km) and normally high impedance of the read-out unit / logger is normally no limitation.

The digital RS-485 output can operate over cable lengths up to 1000 m, depending on the baud-rate used.

9. Customer support

If you require any support for your Kipp & Zonen product please contact your local representative in the first instance. The information can be found in the 'Contact' section (home tab) of our website at **www.kippzonen.com**

Alternatively, you can contact us directly at **www.kippzonen.com/support**

Please include the following information:

- Instrument model
- Instrument serial number
- Details of the fault or problem
- Examples of data files
- Readout device, data acquisition system and operating system
- Interfaces and power supplies
- History of any previous repairs or modifications
- Pictures of the installation
- Overview of the local environment conditions

Kipp & Zonen guarantees that your information will not be shared with other organisations.

10. Keyword index

Term	Explanation
Albedo	The portion of incoming radiation which is reflected by a surface
Azimuth angle	Angle in horizontal direction (0 to 360 °) normally referred to North
Angle of incidence	Incident angle from zenith (0° is vertical, 90° is horizontal)
Cosine response	Radiometer directional response according to the cosine law
Diffuse horizontal irradiance	Solar radiation, scattered by water vapour, dust and other particles as it passes through the atmosphere falling on a horizontal surface (DHI)
Direct normal irradiance	Radiation that has travelled in a straight path from the sun falling on a surface normal to the beam (DNI)
Global horizontal irradiance	Total irradiance falling on a horizontal surface (GHI) Global = Diffuse + (Direct x cos α); α is the solar zenith angle
Irradiance	Radiant flux density (W/m^2)
Long-wave radiation	Radiation with wavelengths from 4 μm to more than 40 μm
Pyranometer	Radiometer for measuring short-wave global radiation
Pyrgeometer	Radiometer for measuring long-wave radiation
Pyrheliometer	Radiometer for measuring direct short-wave radiation
Short-wave radiation	Radiation with wavelengths from approximately 300 nm to 4000 nm (4 μm)
Thermopile	Thermal detector made up of many thermocouple junctions
WMO	World Meteorological Organisation, Geneva, Switzerland
WRC	World Radiation Centre, Davos, Switzerland
WRR	World Radiometric Reference (standard radiation scale) at WRC
WSG	World Standard Group of radiometer at WRC
Zenith angle	Angle from zenith (0 ° is vertical)

Appendices

A. Modbus®

A.1 Modbus® commands

The commands are all according to the Modbus RTU protocols described in the document: 'Modbus® over serial line V1.02' and 'MODBUS application protocol V1.1b' available from the Modbus® organization (www.modbus.org). The commands can be tested using software tools, such as the program 'Modbus Poll' from www.modbustools.com.

The following commands are implemented:

Function	Sub function	Description
0x01	N/A	Read Coils
0x02	N/A	Read Discrete Inputs
0x03	N/A	Read Holding Registers
0x04	N/A	Read Input Register
0x05	N/A	Write Single Coil
0x06	N/A	Write Holding Register
0x10	N/A	Write multiple Registers

The SHP does not make a difference between a 'coil' and a discrete input. The only difference is that a discrete input is read only.

The SHP does not make a difference between a holding register and an input register. The only difference is that an input register is read only.

A.2 Input registers

Input registers are read only

Real-time Processed Data						
PDU address	Parameter	Name	R/W	Type	Mode	Description
0	IO_DEVICE_TYPE	DevType	R	U	All	Device type of the sensor
1	IO_DATAMODEL_VERSION	DataSet	R	U	All	Version of the object data model
2	IO_OPERATIONAL_MODE	DevMode	R	U	All	Operational mode: normal, service, calibration and so on
3	IO_STATUS_FLAGS	Status	R	U	All	Device Status flags
4	IO_SCALE_FACTOR	Range	R	S	All	Range and scale factor sensor data (determines number of decimal places)
5	IO_SENSOR1_DATA	Sensor1	R	S	N,S	Temperature compensated radiation in W/m^2 (Net radiation for SGR)
6	IO_RAW_SENSOR1_DATA	RawData1	R	S	N,S	Net radiation (sensor 1) in W/m^2
7	IO_STDEV_SENSOR1	StDev1	R	S	N,S	Standard deviation IO_SENSOR1_DATA
8	IO_BODY_TEMPERATURE	BodyTemp	R	S	N,S	Body temperature in 0.1 °C
9	IO_EXT_POWER_SENSOR	VSupply	R	S	N,S	External power voltage
10	IO_SENSOR2_DATA	Sensor2	R	S	N,S	Temperature compensated long wave down radiation in W/m^2 (only for SGR)
11	IO_RAW_SENSOR2_DATA	RawData2	R	S	N,S	Long wave down radiation in W/m^2 (only for SGR)
12	IO_STDEV_SENSOR2	StDev2	R	S	N,S	Not used, always 0
13	IO_BODY_TEMP_K	BodyTempK	R	U	N,S	Body temperature in 0.01 °K (only for SGR)
14	IO_AUX_INPUT2	Aux2	R	S	N,S	Not used, always 0
15	IO_AUX_INPUT3	Aux3	R	S	N,S	Not used, always 0
16	IO_DAC_OUTPUT_VOLTAGE	VDAC	R	U	N,S	DAC output voltage or current (actual voltage or current)
17	IO_SELECTED_DAC_INPUT	DacInp	R	U	N,S	DAC selected input voltage

(1) The scale factor defines the format and number of decimal places

Real-time Data A/D Counts					
PDU address	Parameter	R/W	Type	Mode	Description
18	IO_ADC1_COUNTS	R	S32	All	Input voltage sensor 1 in 0.01 µV
19					(R18=MSB, R19=LSB)
20	IO_ADC2_COUNTS	R	S32	All	Not supported, always 0
21					
22	IO_ADC3_COUNTS	R	S32	All	Input voltage body temperature sensor in 0.01 µV
23					(R22=MSB, R23=LSB)
24	IO_ADC4_COUNTS	R	S32	All	Input voltage power sensor in 0.01 µV
25					(R24=MSB, R25=LSB)

Error reports					
PDU address	Parameter	R/W (2)	Type	Mode	Description
26	IO_ERROR_CODE	R	U16	All	Most recent/ actual error code
27	IO_PROTOCOL_ERROR	R	U16	All	Protocol error/communication error
28	IO_ERROR_COUNT_PRIO1	R	U16	All	Error code priority 1
29	IO_ERROR_COUNT_PRIO2	R	U16	All	Error count priority 2
30	IO_RESTART_COUNT	R	U16	All	Number of controlled restarts
31	IO_FALSE_START_COUNT	R	U16	All	Number of uncontrolled restarts
32	IO_SENSOR_ON_TIME	R	U16	All	On time in seconds (MSB word)
33	IO_SENSOR_ON_TIMEL	R	U16	All	On time in seconds (LSB word)
41	IO_BATCH_NUMBER	R	U16	All	Production batch number
42	IO_SERIAL_NUMBER	R	U16	All	Serial number
43	IO_SOFTWARE_VERSION	R	U16	All	Software version
44	IO_HARDWARE_VERSION	R	U16	All	Hardware version
45	IO_NODE_ID	R	U16	All	(MODBUS®/SMA) device address RS-485

(2) Writing any value to input registers 26-33 will reset the contents of the registers

Legend

PDU address	PDU address + 1 = Modbus® register number		
Parameter	Name	Name of the register	
R/W	Read write	**R**	Read only
		R/W	Read/write
Type	Type and size	**U16**	16 bit unsigned integer
		S16	16 bit signed integer
		S32	32 bit signed integer (MSB first, LSB last)
Mode	Operation mode	**N**	available in normal mode
		S	available in service mode
		C	available in calibration mode (not for users)
		F	available in factory mode (not for users)
		All	available in all modes

A.3 Holding registers

Device Control					
PDU address	Parameter	R/W	Type	Mode	Description
34	IO_DEF_SCALE_FACTOR	R/W	S16	All	Default scale factor
35 to 40	Factory use only				

A.4 Read input register

Many of the registers and controls are for remote diagnostics. In this chapter only the most interesting registers and controls are described.

Register 0 IO_DEVICE_TYPE

The device type defines which device is connected. This register can be used to check the type of the connected device.
IO_datamodel_version 102 supports the following type of sensors.

Real-time Processed Data					
Parameter name	Register	R/W	Initial Val	Mode	Description
IO_DEVICE_TYPE	R0	R	65535	All	Selected device type of the sensor
Parameter	Value	# of sensors	1/Sensitivity	Type	
SMP3 (volt version)	601	1	5-20 μV/(W/m²)	Pyranometer	
SMP3 (current loop version)	602	1	5-20 μV/(W/m²)	Pyranometer	
SMP6 (volt version)	619	1	7-14 μV/(W/m²)	Pyranometer	
SMP6 (current version)	620	1	7-14 μV/(W/m²)	Pyranometer	
SMP10 (volt version)	617	1	7-14 μV/(W/m²)	Pyranometer	
SMP10 (current version)	618	1	7-14 μV/(W/m²)	Pyranometer	
SMP11 (volt version)	603	1	7-14 μV/(W/m²)	Pyranometer	
SMP11 (current loop version)	604	1	7-14 μV/(W/m²)	Pyranometer	
SMP21 (volt version)	605	1	7-14 μV/(W/m²)	Pyranometer	
SMP21 (current loop version)	606	1	7-14 μV/(W/m²)	Pyranometer	
SMP22 (volt version)	607	1	7-14 μV/(W/m²)	Pyranometer	
SMP22 (current loop version)	608	1	7-14 μV/(W/m²)	Pyranometer	
SGR3 (volt version)	609	2*	5-15 μV/(W/m²)	Pyrgeometer	
SGR3 (current loop version)	610	2*	5-15 μV/(W/m²)	Pyrgeometer	
SGR4 (volt version)	611	2*	5-15 μV/(W/m²)	Pyrgeometer	
SGR4 (current loop version)	612	2*	5-15 μV/(W/m²)	Pyrgeometer	
SHP1 (volt version)	613	1	7-14 μV/(W/m²)	Pyrheliometer	
SHP1 (current loop version)	614	1	7-14 μV/(W/m²)	Pyrheliometer	
SUV5 (volt version)	615	1	300 - 500 μV/(W/m²)	UV Radiometer	
SUV5 (current loop version)	616	1	300 - 500 μV/(W/m²)	UV Radiometer	

A.4 Holding registers

Device Control

34	IO_DEF_SCALE_FACTOR	R/W	S16	All	Default scale factor
35 to 40	Factory use only				

A.5 Read input register

Many of the registers and controls are for remote diagnostics. In this chapter only the most interesting registers and controls are described.

Register 0 IO_DEVICE_TYPE

The device type defines which device is connected. This register can be used to check the type of the connected device.
IO_datamodel_version 102 supports the following type of sensors.

Register 5 **IO_SENSOR1_DATA**

This register holds the actual data (solar radiation) measured by the sensor. The solar radiation is measured in W/m².

If the register **IO_SCALE_FACTOR** is not set to 0 then you must multiply or divide the data as described under register 4.

The raw data from the sensor is calibrated, linearized; temperature compensated and filtered using 2 different kinds of filters (See **IO_FAST_RESPONSE** and **IO_TRACKING_FILTER**).

Register 6 **IO_RAW_SENSOR1_DATA**

The raw sensor data is calibrated but not linearized and temperature compensated. If the register **IO_SCALE_FACTOR** is not set to 0 then you must multiply or divide the data as described under register 4, **IO_SCALE_FACTOR**.

Register 7 **IO_STDEV_SENSOR1**

This register is used to calculate the standard deviation over the signal. When the register is read the data is sent to the computer and at the same time a new calculation is started. The next time register 7 is read the standard deviation over the last period is sent to the computer and a new calculation is started. If the poll frequency is quite high (for example 1 poll per second) then the standard deviation will be zero or almost zero, but if the poll frequency is very low then the standard deviation can be quite high, indicating that the data in register 5 or 6 changed dramatically since the last poll. The standard deviation is measured in 0.1 W/m². To convert the data to a floating point, make the following calculation:

(floating point) result = (integer) register (IO_STDEV_SENSOR1) / 10.0

Register 8 **IO_BODY_TEMPERATURE**

The body temperature sensor measures the temperature of the body in 0.1°C.

The convert the data to a floating point number, make the following calculation:

(floating point) result = (integer) register (IO_BODY_TEMPERATURE) / 10.0

Register 9 **IO_EXT_POWER_SENSOR**

The Ext power sensor measured the external voltage applied to the sensor in 0.1 Volt.

The convert the data to a floating point number, make the following calculation:

(floating point) result = (integer) register (IO_EXT_POWER_SENSOR) / 10.0

Example

Read registers: ‘operational mode to external power’ from Modbus® device with address 1.

Tx transmitted data to the smart sensor
Rx received data from the smart sensor

SendModbusRequest (0x04, 1, IO_OPERATIONAL_MODE, 8);
Tx 01 04 00 02 00 08 50 0C
Rx 01 04 10 00 01 00 00 00 00 03 E5 03 E5 00 00 00 F8 00 EA 66 12

Explanation of the received bytes:

01	= MODBUS address
04	= read input registers
10	= number of received data bytes
00 01	= operational mode (mode 1)
00 00	= status flags (none)
00 00	= scale factor = 0 = 1x
03 E5	= 997 decimal = sensor 1 data in W/m²
03 E5	= 997 decimal = raw sensor 1 data in W/m²
00 00	= 0 = standard deviation sensor 1
00 F8	= 248 = 24.8°C.
00 EA	= 234 = 23.4 Volt
66 12	= MODBUS checksum (CRC16)

A.5 Discrete inputs

A discrete input can be true or false. A discrete input is read only; a coil can be read or written.

Status indicators

Input	Parameter	R/W	Def.	Mode	Description
0	IO_FALSE	R	0	All	Always false (for testing only)
1	IO_TRUE	R	1	All	Always true (for testing only)
2	IO_VOID_DATA_FLAG	R	*	All	Void signal, 1=unstable signal, temperature too low or too high
3	IO_OVERFLOW_ERROR	R	*	All	Overflow, signal out of range
4	IO_UNDEFLOW_ERROR	R	*	All	Underflow signal out of range
5	IO_ERROR_FLAG	R	*	All	General hardware error (set if one of the H/W error flags is set)
6	IO_ADC_ERROR	R	*	All	Hardware error A/D converter
7	IO_DAC_ERROR	R	*	All	Hardware error D/A converter
8	IO_CALIBRATION_ERROR	R	*	All	Calibration checksum error
9	IO_UPDATE_FAILED	R	*	All	Update calibration parameters failed

Legend

Input	Discrete input	Modbus® discrete input 0 is the first discrete input	
Coil	Modbus Coil	A coil can be read or written.	
Parameter	Name	Name of the register	
R/W	Read write	**R**	Read only
		R/W	Read/write
Def	Default value	default value at power on (0, 1 or *) * = undefined	
Mode	operation mode	**N**	available in normal mode
		S	available in service mode
		C	available in calibration mode (not for users)
		F	available in factory mode (not for users)
		All	available in all modes

Inputs can be read in all modes but some coils can't be written in normal mode or service mode.

A.6 Coils

Device control					
Coil	Parameter	R/W	Def.	Mode	Description
10	IO_CLEAR_ERROR	R/W	0	All	Select normal operation and clear error (1=clear error)
11 to 17	FACTORY USE ONLY				
18	IO_RESTART_MODBUS	R/W	0	All	Restart the device with modbus® protocol
19	FACTORY USE ONLY				
20	IO_ROUNDOFF	R/W	1	S,N	Enable rounding of sensor data
21	IO_AUTO_RANGE	R/W	0	S,N	Enable auto range mode (0=no auto range)
22	IO_FASTRESPONSE	R/W	0	S,N	Enable fast response filter (0=no filter)
23	IO_TRACKING_FILTER	R/W	1	S,N	Enable tracking filter (0=no filter)

Note The default values of the device options are stored in non-volatile memory. The default values can be overruled during operation. However, at power-on the default values are restored and the smart sensor will start up with the default values stored in the non-volatile memory.

ADC CONTROL					
Coil	Parameter	R/W	Def.	Mode	Description
24 to 34	Factory use only				

A.7 Read write holding registers

Register 34 **IO_DEF_SCALE_FACTOR**

The default scale factor is set in the factory mode or service mode and is stored in non-volatile memory. The default scale factor stored in non-volatile memory is always set after a power-on. However it is possible to change the default setting during operation by writing a value to the register 34.

Note This value is not stored in non-volatile memory and is overwritten with the default value at power on.

The following values are valid:
Scale factor = 2
Scale factor = 1
Scale factor = 0
Scale factor = -1
Scale factor 0 is the default value. See also input register 4 **IO_SCALE_FACTOR**.

A.8 Read discrete inputs

Discrete input 0 **IO_FALSE** This discrete input is always false

Discrete input 1 **IO_TRUE** This discrete input is always true

Discrete input 2 **IO_VOID_DATA_FLAG**

The void data flag is raised when the data in register **IO_SENSOR1_DATA** or **IO_RAW_SENSOR1_DAT**A is not valid, because the body temperature of the sensor is too low or too high, when there is an internal overflow condition, because a calculation is out of range or a division by zero occurred, the reference voltage of the ADC is not stable or the digital filter is not stable. When the **IO_VOID_DATA_FLAG** is set, bit 0 in the **IO_STATUS_FLAGS** is also set.

The **IO_VOID_DATA_FLAG** and bit 0 of the **IO_STATUS_FLAGS** are cleared when the **IO_VOID_DATA_FLAG** is read by the computer.

Discrete input 3 IO_OVERFLOW_ERROR
This discrete input is raised when an out of range condition occurs and the sensor data (see **IO_SENSOR1_DATA**) is above the maximum value specified by the calibration program or above 29,999. The typical maximum value is 4000 W/m².

When the **IO_OVERFLOW_ERRO**R is set, bit 1 in the **IO_STATUS_FLAGS** is also set.

The **IO_OVERFLOW_ERROR** and bit 1 of the **IO_STATUS_FLAGS** are cleared when the **IO_OVERFLOW_ERROR** is read by the computer.

Discrete input 4 IO_UNDERFLOW_ERROR
This discrete input is raised when an underflow condition occurs and the sensor data (see **IO_SENSOR1_DATA**) is below the minimum value specified by the calibration program or below -29,999. The typical minimum value is -400 W/m².

When the **IO_UNDERFLOW_ERROR** is set, bit 2 in the **IO_STATUS_FLAGS** is also set.

The **IO_UNDERFLOW_ERROR** and bit 2 of the **IO_STATUS_FLAGS** are cleared when the **IO_UNDERFLOW_ERROR** is read by the computer.

Discrete input 5 IO_ERROR_FLAG
The error flag is raised when there is a (fatal or correctable) hardware error or software error such as: ADC error, DAC error, calibration error or when the update of the calibration data failed. When the **IO_ERROR_FLAG** is raised the error code is copied to the register **IO_ERROR_CODE** (see register 26).

The error flag is cleared when a true condition is written to the coil: **'IO_CLEAR_ERROR**'. This has no effect when the error is fatal or not resolvable such as a calibration error.

The error flag is always set after a power up, this is to indicate the power went off, or a restart occurred. The computer should raise the **IO_CLEAR_ERROR** in order to reset the error flag.

Discrete input 6 IO_ADC_ERROR
This flag is raised when the A/D converter responsible for the conversion of the analogue signals to digital signals detected a failure (hard or software).

The ADC error flag is cleared when a true condition is written to the coil: **'IO_CLEAR_ERROR'** and the error produced by the ADC, is not fatal.

Discrete input 7 IO_DAC_ERROR
This flag is raised when the D/A converter responsible for the conversion of the digital signal to the analogue output signal detected a failure (hard or software).

The DAC error flag is cleared when a true condition is written to the coil: **'IO_CLEAR_ERROR'** and the error produced by the DAC, is not fatal.

Discrete input 8 IO_CALIBRATION_ERROR

The calibration error flag is raised when the sensor was not calibrated or a checksum error was detected in the calibration data. This flag can't be cleared unless the sensor is sent back to the manufacturer or dealer for a re-calibration.

Discrete input 9 IO_UPDATE_FAILED

The update failed is raised when data is written to the non-volatile memory and the update failed. This can happen in calibration mode when calibration data in written to non-volatile memory or in the service mode when device options are written to the non-volatile memory.

If this error is set you should retry the last update action. If the error does not disappear then there could be a hardware problem with the non-volatile memory (EEPROM).

A.9 Read write discrete coils

Coil 10 IO_CLEAR_ERROR

Setting this coil will clear the error only when the error is a non-fatal error. Reading this coil will always return a 0. The coil **IO_CLEAR_ERROR** can be used to select the normal mode (see **IO_OPERATIONAL_MODE**).

The smart sensors will always start-up in the normal mode.

Note Use **IO_CLEAR_ERROR** to return to the normal mode.

Coil 20 IO_ROUNDOFF

Setting this coil enables rounding of the data presented in **IO_SENSOR1_DATA** and **IO_RAW_SENSOR1_DATA**.

If not set then the customer should round off the received data before processing the data.

The default value after power on is ON.

If **IO_ROUNDOFF** is cleared, then the sensor is not calibrated and could produce more digits, than there are significant digits.

Coil 21 IO_AUTO_RANGE

Setting this coil enables the auto-range feature. The auto-range feature increases the number of digits for small signals

The default value after power on is OFF.

If **IO_AUTO_RANGE** is set then the sensor is not calibrated and could produce more digits, than there are significant digits.

Coil 22 IO_FASTRESPONSE

Setting this coil enables the fast response filter. This filter increases the step response of the sensor. Disabling the fast response give the SHP pyrheliometers the same response time as the CMP equivalents.

The default value after power on is ON.

Coil 23 **IO_TRACKING_FILTER**

Setting to this coil enables the tracking filter. The tracking filter reduces the noise of the signal. However, when the filter is on, the step response on a sudden signal change is decreased. The smart sensor uses variable filter constants to minimize the effect on the step response.

The default value after power on is OFF.

A.10 Requesting serial number

Register 41 **IO_BATCH_NUMBER**

The batch number defines the production year of the smart sensor, 11 = 2011, 12=2012 etc.

Register 42 **IO_SERIAL_NUMBER**

Register 42 defines the 4 digits serial number of the smart sensor. Only the combination of the batch number and serial number is unique.

A.11 Simple demonstration program

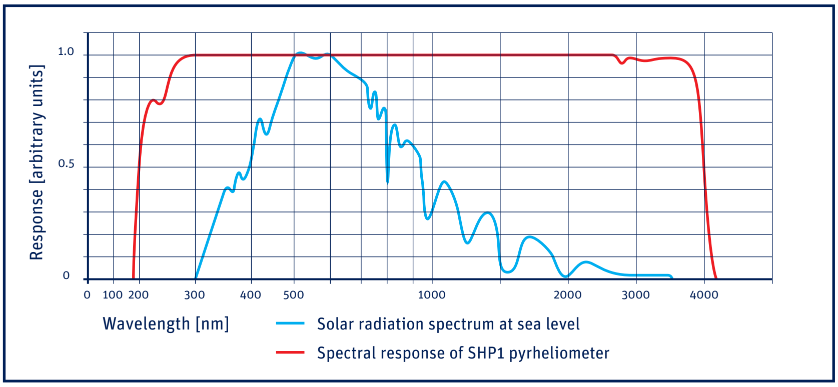
The simple ‘C’ program below will show how to read the sensor data and how to deal with errors. The program will read the registers: ‘operational mode, status flags, scale factor, and sensor data’ from Modbus® device with address 2 into registers uOperationMode, uStatusFlags, iScaleFactor and iSensorData. Then the program will check the operation mode (must be ‘normal’) and if there are no errors flags set in iStatusFlags. If there is an error then set the **IO_ERROR_FLAG**.

```
UInt16      uOperationalMode = 0;
UInt16      uStatusFlags = 0;
Int16       iScaleFactor = 0;
Int16       iSensorData = 0;
float       fSensorData = 0;

int main (void)
{
            while (true)
            {
                        // Send MODBUS request 0x04 Read input registers to slave 2
                        // Get modus data will wait for the answer and copies the data to registers
                        // uOperationalMode, uStatusFlags, iScaleFactor and iSensorData

                        SendModbusRequest (0x04, 2, IO_OPERATIONAL_MODE, 4);
                        WaitModbusReply ();
                        GetModbusData ();

                        If (uOperationalMode != 1)
                        {
                                    // Send MODBUS request 0x05 write single coil to slave 2
                                    SendModbusRequest (0x05, 2, IO_CLEAR_ERRROR, true);
                                    WaitModbusReply ();
                        }
                        else if (uStatusFlags != 0)
                        {
                                    SendModbusRequest (0x05, 2, IO_CLEAR_ERRROR, true);
                                    WaitModbusReply ();
                        }
                        switch (iScaleFactor)
                        {
                                    case 2: fSensorData = (float)(iSensorData) / 100.0;
                                    case 1: fSensorData = (float)(iSensorData) / 10.0;
                                    case 0: fSensorData = (float)(iSensorData);
                                    case -1: fSensorData = (float)(iSensorData) * 10.0;
                                    default: fSensorData = 0.0;
                        }
                        // wait 1 second
                        Delay (1000);
            }
}
```

B. Pyrheliometer physical properties

B.1 Spectral range

The spectrum of the solar radiation reaching the Earth's surface is in the wavelength range between 280 nm and 4000 nm, extending from ultraviolet (UV) to the far infrared (FIR). Due to the excellent physical properties of the quartz window and black absorber paint, Kipp & Zonen SHP1 pyrheliometers are equally sensitive in a wide spectral range. 99% of the total energy will be absorbed by the thermal detector.



B.2 Sensitivity

For the SHP1 pyrheliometers the physical sensitivities are converted to a digital output that is identical for all sensors. The SHP1-V has an analogue output of 0 to 1 Volt for -200 to 2000 W/m². The SHP1-A output is 4 to 20 mA for 0 to 1600 W/m².

B.3 Response time

Any measuring device requires a certain time to react to a change in the parameter being measured. The radiometer requires time to respond to changes in the incident radiation. The response time is normally quoted as the time for the output to reach 95% (sometimes 1/e, 63%) of the final value following a step-change in irradiance. It is determined by the physical properties of the thermopile and the radiometer construction. SHP1 pyrheliometer is set to digitally accelerate the physical response.

B.4 Non-linearity

The non-linearity of a pyrheliometer is the percentage deviation in the sensitivity over an irradiance range from 0 to 1000 W/m² compared to the sensitivity calibration irradiance of 500 W/m². The non-linear effect is due to convective and radiative heat losses at the black absorber surface which make the conditional thermal equilibrium of the radiometer non-linear.

B.5 Tempearture dependence

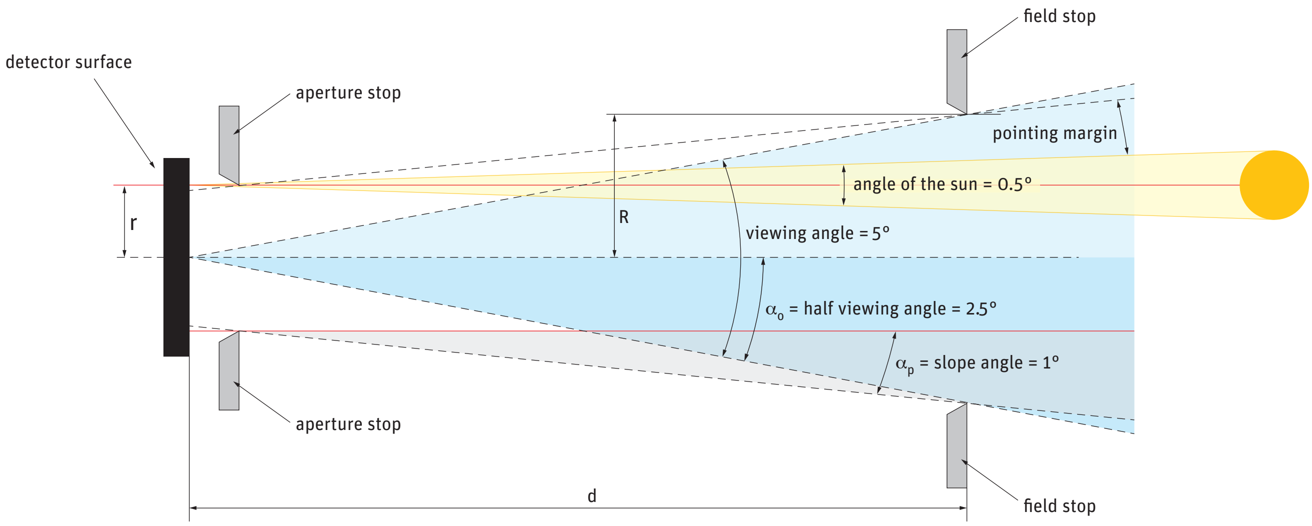
The sensitivity change of the radiometer with ambient temperature change is related to the thermo-dynamics of the radiometer construction. The temperature dependence is given as percentage deviation with respect to the calibrated sensitivity at +20 °C. The SHP1 pyrheliometer has an integrated temperature sensor and use a fourth-order polynomial function to actively correct for temperature errors over a -40 °C to +70 °C range.

B.6 Operating temperature

The operating temperature range of the radiometer is determined by the physical properties of the individual parts. Within the specified temperature range Kipp & Zonen radiometers can be operated safely. Outside this temperature range special precautions should be taken to prevent any physical damage or performance loss of the radiometer. Please contact your Kipp & Zonen representative for further information regarding operation in unusually harsh temperature conditions.

B.7 Field of view

The beam of light that reaches the detector is limited by the field and aperture stops. The slope and viewing angles are determined by R, r and d.



For the SHP1 the full viewing angle is 5 °, the slope angle is 1 °. The sun, as seen from the detector, occupies a solid angle of 0.5 °. A 100 % response can be expected only if the sun is entirely within the slope angle. This is the case when tracking accuracy is better than slope angle minus half the solar angle.

Concluding, the tracking accuracy of the sun tracker should be better than the 0.75 ° pointing margin of the pyrheliometer, and therefore within 0.5 ° of ideal.

B.8 Maximum irradiance

The maximum irradiance is defined as the total irradiance level beyond which the output is no longer linear and out of specifications. The analogue output for the SHP1 is set to 2000 W/m², which is sufficient under normal atmospheric conditions. For special applications the SHP1 can be set higher, up to 4000 W/².

B.9 Non-stability

This is the percentage change in sensitivity over a period of one year. This effect is mostly due to degradation by UV radiation of the black absorber coating on the thermopile surface.

B.10 Spectral selectivity

Spectral selectivity is the variation of the window transmittance and absorption coefficient of the black detector coating with wavelength and is commonly specified as % of the mean value.

B.11 Environmental

The SHP1 is intended for outdoor use under all expected weather conditions. The radiometer complies with IP 67 and their solid mechanical construction is suitable to be used under all environmental conditions within the specified ranges.

B.12 Uncertainty

The measurement uncertainty of a pyrheliometer can be described as the maximum expected hourly or daily uncertainty with respect to the 'absolute truth'. The confidence level is 95%, which means that 95% of the data-points lie within the given uncertainty interval representing the absolute value. Kipp & Zonen empirically determine uncertainty figures based on many years of field measurements for typical operating conditions.

When a pyrheliometer is in operation, the performance of it is correlated to a number of parameters, such as temperature, level of irradiance, etc. If the conditions differ significantly from calibration conditions, uncertainty in the calculated irradiances must be expected.

C. Pyrheliometer classification to ISO 9060:1990

Ref. No.	Specification	ISO 9060:1990 classification			SHP1
		Secondary Standard	First Class	Second Class	First Class
1	Response time (95% response)	< 15 s	< 20 s	< 30 s	< 2 s
2	Zero off-set Response 5 K/hr change in ambient temperature	± 1 W/m²	± 3 W/m²	± 6 W/m²	< 1 W/m²
3a	Non-stability (change per year, percentage of full scale)	± 0.5 %	± 1 %	± 2 %	< 0.5 %
3b	Non-linearity (percentage deviation from the responsivity at 500 W/m² due to any change of irradiance within the range 100 to 1000 W/m²)	± 0.2 %	± 0.5 %	± 2 %	< 0.2 %
3d	Spectral sensitivity (percentage of deviation of the product of spectral absorptance and spectral transmittance from the corresponding mean within the range of 0.3 µm to 3 µm)	± 0.5 %	± 1 %	± 5 %	< 0.5 %
3e	Temperature response (percentage deviation due to change in ambient temperature within an interval of 50 K)	± 1 %	± 2 %	± 10 %	< 0.5 % -30°C to +60°C
3f	Tilt response (percentage deviation from the responsivity at 0° tilt, horizontal, due to change in tilt from 0° to 90° at 1000 W/m² irradiance)	± 0.2 %	± 0.5 %	± 2 %	< 0.5 %

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