DR01
First Class pyrheliometer

DR02
Fast response First Class pyrheliometer

USER MANUAL

DR01 DR02 manual v1222

Warnings and safety issues:

DR01 and DR02 are passive sensors, and do not need any power. Window heating however does require 12 VDC for heating at 0.5 Watt.

Putting more than 12 Volt across DR01 or DR02 sensor wiring can lead to permanent damage to the sensor.

DR02 should not be used in combination with datalogging with open circuit detection.

Contents

List of symbols

Voltage output	U	µV
Sensitivity of the DR01 / DR02	E	$\mu V/(Wm^{-2})$
Solar irradiance		Wm^{-2}

Introduction

DR01 and DR02 are research grade direct normal incidence (DNI) solar irradiance sensors, also known as pyrheliometers. They comply with 'First Class' classification, as per the latest ISO 9060 and WMO standards. A unique product feature is the heated window. DR01 and DR02 are typically mounted on a solar tracker.
DR02 is the fast-response equivalent of DR01. The only difference is in detector technology, this results in a much faster response time (95%) for DR02: 1s instead of traditional 18s.

In this manual, DR01 will be mentioned; DR02 wil be mentioned only in case this is necessary.
DR01 foreoptic assembly features a precision ground and polished quartz window, for true spectral solar transmission ranging from 0.2 - 4.0 µm. As per the latest ISO 9060 and WMO standards, the full opening view angle of the DR01 is collimated precisely to 5 degrees, for direct normal incidence solar irradiance measurement.
Capable of measuring up to 2000 Wm^{-2}, the DR01 pyrheliometer can be deployed anywhere on earth. The instrument employs a passive thermopile-based sensing technology that generates a low level DC millivolt output signal proportional to the normal incident direct solar flux received at the detector surface. The DR01 also features a thermally isolated low power window heater in the foreoptic; when cycled on/off prior to sunrise the heater effectively eliminates the formation of dew on the pyrheliometer window. This results in improved post sunrise measurement accuracy, as well as lower maintenance, as it requires less cleaning.
Determining direct solar irradiance with the DR01 requires connection to a data acquisition and a two-axis solar tracker platform. Typical pyrheliometer measurement applications include solar renewable resource assessment, concentrated PV electricity output validation, solar collector and PV panel efficiency validation, material testing research.

Each DR01 is calibrated upon manufacture and delivered standard with a WRR (World Radiometric Reference) traceable certificate of calibration.
Options include: extended cable lengths, AC100 / AC420 amplifiers, temperature sensors (Pt100 or 10 kOhm thermistor)
Various tracking solutions can be offered by Hukseflux.

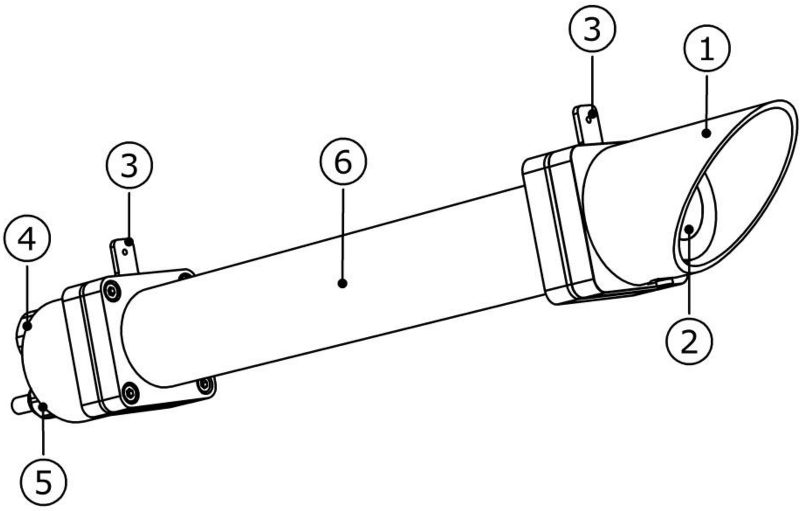

Figure 0.1 DR01 pyrheliometer, (1) protection cap, (2) window with heater, (3) s ight, (4) humidity indicator, (5) cable gland, (6) aperture tube

1. Checking at delivery

1.1 Presence of parts

Arriving at the customer, the delivery should include:
- pyrheliometer DR01
- cable of the length as ordered
- calibration certificate matching the instrument serial number
- any other options as ordered

It is recommended to store the certificate in a safe place.

1.2 Functionality of the instrument

Testing the instrument can be performed by using a simple handheld multimeter. See Chapter 6.2 on testing and troubleshooting on this subject.
The programming of dataloggers is the responsibility of the user. Please contact the supplier to see if directions for use with your system are available.
In case programming for similar instruments is available, this can typically also be used.

2. Instrument principle

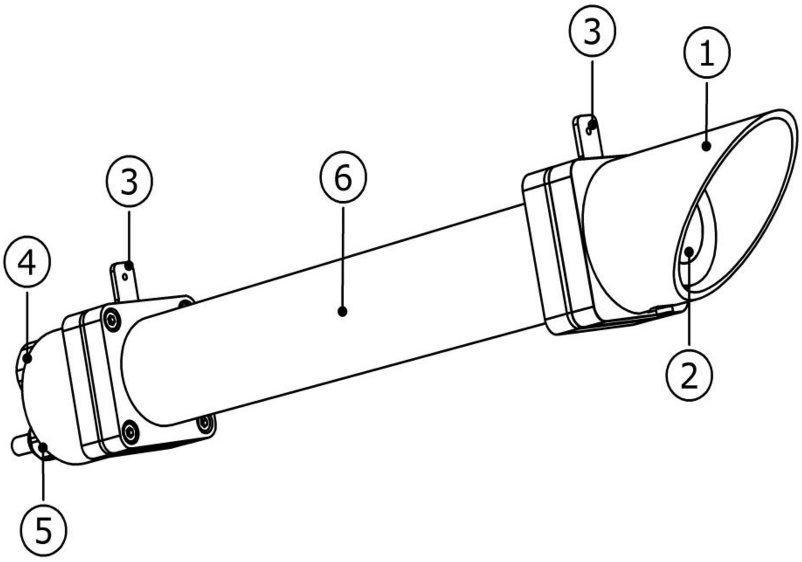

Figure 2.1 DR01 pyrheliometer, (1) protection cap, (2) window with heater, (3) sight, (4) humidity indicator, (5) cable gland, (6) diaphragm tube

DR01's scientific name is pyrheliometer. A pyrheliometer measures the solar radiation flux with a field of view of 5 degrees.
The solar radiation spectrum extends roughly from 300 to 2800 nm. It follows that a pyrheliometer should cover that spectrum with a spectral sensitivity that is as "flat" as possible.

For a correct measurement the DR01 should be pointed at the sun. In order to attain the proper spectral characteristics, a pyrheliometer's main components are:
1 a thermopile sensor with a black coating. This sensor absorbs all solar radiation, has a flat spectrum from visible light to infra-red and has a near-perfect cosine response.
2 a quartz window. This window limits the spectral response from 200 to 4000 nm (cutting off the part above 4000 nm). Another function of the window is that it shields the thermopile sensor from convection.

The black coating on the thermopile sensor absorbs the solar radiation. This radiation is converted to heat, which flows through the sensor to the DR01 housing. The thermopile sensor generates a voltage output signal that is proportional to the solar radiation.

Smart Sensing SENSOVANT

3. Specifications of DR01 / DR02

DR01 serves to measure the solar radiation flux that is incident on a plane surface in Wm^{-2} from a 5 degrees field of view (also called direct normal incidence radiation). Working completely passive, using a thermopile sensor, DR01 generates a small output voltage proportional to this flux. The front window contains a heater that can be put on at nighttime to prevent dew deposition. It can only be used in combination with a suitable measurement system and tracker. DR02 is a fast-response version of DR01.

Table 3.1 Specifications of DR01 and DR02

	DR01 and DR02 ISO Specifications	
3	Overall classification according to ISO 9060:1994	First class pyrheliometer
4	Response time (time for 95% response)	DR01: 18 s DR02: 1 s
5	Zero offset (response to 5 K/h change in ambient temperature)	< ±1 Wm^{-2}
6	Non-stability (percentage change in responsivity per year)	< ±1%
7	Non-Linearity (percentage deviation from responsivity at 500 Wm^{-2} due to the change in irradiance within 100-1000 Wm^{-2})	< ±0.5 %
8	Spectral selectivity (percentage deviation of the product of spectral absorptance and spectral transmittance from the corresponding mean within 0.35 µm and 1.5 µm)	< ±1 %
9	Temperature response (percentage deviation due to change in ambient temperature within an interval of 50 K)	< ±1 %
10	Tilt response (percentage deviation from the responsivity at 0° tilt (horizontal) due to change in tilt from 0-90° at 1000 Wm^{-2} irradiance)	< ±0.5 %
	DR01 and DR02 additional measurement specifications	
12	Sensitivity	7-15 µV/(Wm^{-2})
13	Expected voltage output	Application with natural solar radiation: -0.1 to +30 mV
14	Operating temperature	-40 to +80 ˚C
15	Sensor resistance	DR01: between 400 and 500 Ohms DR02: between 150 and 250 Ohms
16	Power required	Zero (passive sensor), see also heating
17	Range	To 2000 Wm^{-2}

18	Expected accuracy for daily sums	± 2%
19	Spectral range (the spectral responsivity of field pyrheliometers is limited to the range approximately 0.3 µm to 3 µm, depending on the spectral transmittance of the window which protects the receiver surface)	200 to 4000 nm
20	Drying cartridge/ humidity indicator	Bag of silica gel, 0.5 g, 35 x 20 mm Humidity indicator B2
21	Required readout:	1 differential voltage channel or 1 single ended voltage channel
22	Programming	= U / E
23	Heating	Front window: 0.5 Watt @ 12 VDC, typically activated during nighttime only to prevent dew deposition
24	Standard cable length / diameter	5 m / 5 mm
25	Cable gland	Accepts cable diameter from 3 to 6.5 mm
26	Cable replacement	Cable can be replaced by the user
27	Weight including 5 m cable, size	1.4 kg box of 43 x 11 x 11 cm
28	Tracking	Not included, preferably within 1 degree
	Calibration	
29	Calibration traceability	To WRR, procedure according to ISO 9059
30	Recommended recalibration interval	Every 2 years (sensitivity)
	Options	
31	Cable extension	Longer cables can be supplied on request. Specify multiple of 5m
32	Amplifiers	AC100 and AC420
33	Temperature sensor	Pt100 or 10K thermistor can be added DR01-T1 includes a Pt100 DR01-T2 includes a 10K thermistor

DR01 and DR02 also comply with WMO specifications

4. Installation

4.1 Installation

DR01 is to be installed on a tracker, with an accuracy of 1 degree form true solar position. The mounting should be done by clamping around the DR01 tube (1.5 inch or 38 mm).

4.2 Electrical connection

In order to operate, DR01 should be connected to a measurement system, or datalogger.

DR01 is a passive sensor that does not need any power.

DR02 should not be used in combination with datalogging with open circuit detection.

Cables generally act as a source of distortion, by picking up capacitive noise. It is a general recommendation to keep the distance between data logger or amplifier and sensor as short as possible. For cable extension, see the appendix on this subject.

Table 4.2.1 The electrical connection of DR01. Heater polarity is not important.

PCB connection	Description	Wire colour
8	Thermopile [+]	White
7	Thermopile [-]	Green
1	Temperature sensor [+] (if present)	Red
2	Temperature sensor [+] (if present)	Brown
3	Temperature sensor [-] (if present)	Yellow
4	Temperature sensor [-] (if present)	Blue
5	Heater 12VDC [+]	Pink
6	Heater 12VDC [-]	Grey
Ground	Ground	Black

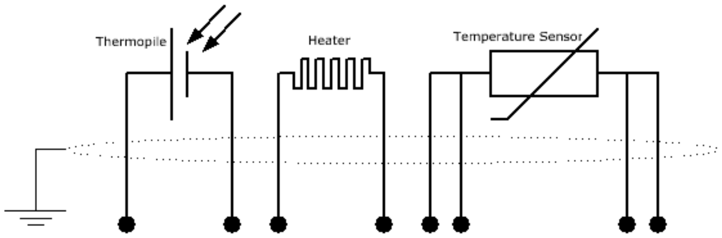

Figure 4.2.1 Electrical diagram of DR01 thermopile detector. The heater is a simple resistor on a separate cable. Temperature sensor is only present if ordered.

5. Dimensions

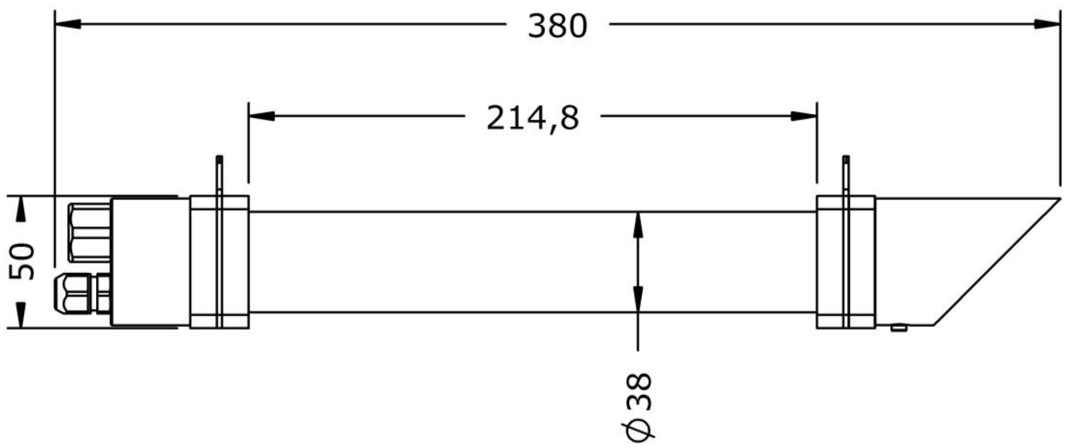

Figure 5.1 Dimensions of DR01 in mm. Tube diameter is 38 mm, approximately 1.5 inch.

6. Maintenance and troubleshooting

6.1 Maintenance

Once installed DR01 is essentially maintenance free.
Periodically dessicant may be replaced.
Usually errors in functionality will appear as unreasonably large or unreasonably small measured values.
As a general rule, this means that a critical review of the measured data is the best form of maintenance.

Recommendations for maintenance are:

1. Critical review of data
2. Cleaning of foreoptic by water or alcohol
3. Inspection of interior of foreoptic; no condensation
4. Dessicant inspection : change in case the humidity indicator has turned pink. Regeneration is possible by heating more than 3 hours at 120 °C. Spanner size required for removal of dessicant is 20.
5. Pointing inspection: daily inspection against sight of the instrument.
6. Inspection of cables for open connections
7. Recalibration: suggested every 2 years, typically by intercomparison with a higher standard in the field.

6.2 Testing and troubleshooting

This paragraph contains information that can be used for testing of the instrument and to make a diagnosis whenever the sensor does not function.

1. Check the impedance of the sensor between the green (-) and white (+) wire. Use a multimeter at the 1000 ohms range. (500 ohms for DR02).
   Measure the impedance at the sensor wires, first with one polarity, than reverse polarity. Take the average value. The typical impedance of the wiring is 0.1 ohm/m. Typical impedance should be the typical sensor impedance of DR01 (400-500 ohms) or DR02 (150-250 ohms) plus 1 ohm for the total resistance of two wires (back and forth) of each 5 meters. Infinite indicates a broken circuit; zero indicates a short circuit
2. Check if the sensor reacts to light: put the multimeter at its most sensitive range of DC voltage measurement, typically 100 microvolt range or lower and expose the sensor to a strong light source, for instance a 100 Watt light bulb at 10 centimeter distance. The signal should read several millivolts now
3. Darken the sensor either by putting something over it or switching off the light. The instrument voltage output should go down and within one minute approach zero mV
4. Check if the right calibration factor is entered into the algorithm. Please note that each sensor has its own individual calibration factor
5. Check if the voltage reading is divided by the calibration factor by review of the algorithm
6. Check the condition of the leads at the logger
7. Check the cabling condition looking for cable breaks

8. Check the range of the data logger; heat flux can be negative (this could be out of range) or the amplitude could be out of range
9. Check the data acquisition by applying a mV source to it in the 1 mV range
10. Check the presence of strong sources of electromagnetic radiation (radar, radio etc.)
11. Check the condition of the shielding
12. Check the condition of the sensor cable

7. Requirements for data acquisition / amplification

Table 7.1 Requirements for data acquisition and amplification equipment.

1	Capability to measure microvolt signals	Preferably: 5 microvolt accuracy Minimum requirement: 20 microvolt accuracy (both across the entire expected temperature range of the acquisition / amplification equipment)
2	Capability for the datalogger or the software	To store data, and to perform division by the sensitivity to calculate the solar irradiance
3	Heating power	Heating is not a necessity. When used: 0.5 W at 12 VDC
4	Warning	DR02 should not be used in combination with datalogging with open circuit detection.

8. Appendices

8.1 Appendix on cable extension / replacement

DR01 is equipped with one cable for the detector and heater. It is a general recommendation to keep the distance between datalogger or amplifier and sensor as short as possible. Cables generally act as a source of distortion, by picking up capacitive noise. DR01 signal cable can however be extended without any problem to 100 meters. If done properly, the sensor signal, although small, will not significantly degrade because the sensor impedance is very low.
Cable and connection specifications are summarised below.

NOTE: the body of DR01 contains connector blocks that can be used for internal connection of a new cable. Usually it is easier to connect a new longer cable than to extend an existing cable.

Table 8.1.1 Spe cifications for cable extension

1	Cable	8-wire shielded, copper core
2	Core resistance	0.1 /m or lower
3	Outer diameter	(preferred) 5 mm
4	Outer sheet	(preferred) polyurethane (for good stability in outdoor applications).
5	Connection	Either solder the new cable core and shield to the original sensor cable, and make a waterproof connection using cable shrink, or use gold plated waterproof connectors.

8.2 Appendix on calibration

The World Radiometric Reference (WRR) is the measurement standard representing the SI unit of irradiance. It was introduced in order to ensure world-wide homogeneity of solar radiation measurements and is in use since 1980.
The WRR was determined from the weighted mean of the measurements of a group of 15 absolute cavity radiometers which were fully characterized. It has an estimated accuracy of 0.3%. The WMO introduced its mandatory use in its status in 1979.

The world-wide homogeneity of the meteorological radiation measurements is guaranteed by the World Radiation Centre in Davos Switzerland, by maintaining the World Standard Group (WSG) which materializes the World Radiometric Reference.

http://www.pmodwrc.ch/

The Sensovant standard is traceable to an outdoor WRR calibration. Some small corrections are made to transfer this calibration to the Sensovant standard conditions:

sun at zenith and 500 W/m2 irradiance level. (during the outdoor calibration the sun is typically at 20-40 degrees zenith angle, and the total irradiance at a 700 W/m2 level.

Recalibration of field pyrheliometers is typically done by comparison in the field to a reference pyrheliometer.
Sensovant uses an indoor calibration.

The main Sensovant recommendation for re-calibration is, if possible, to perform calibration relative to a higher reference under clear sky conditions.

8.3 Appendix on sensor coating

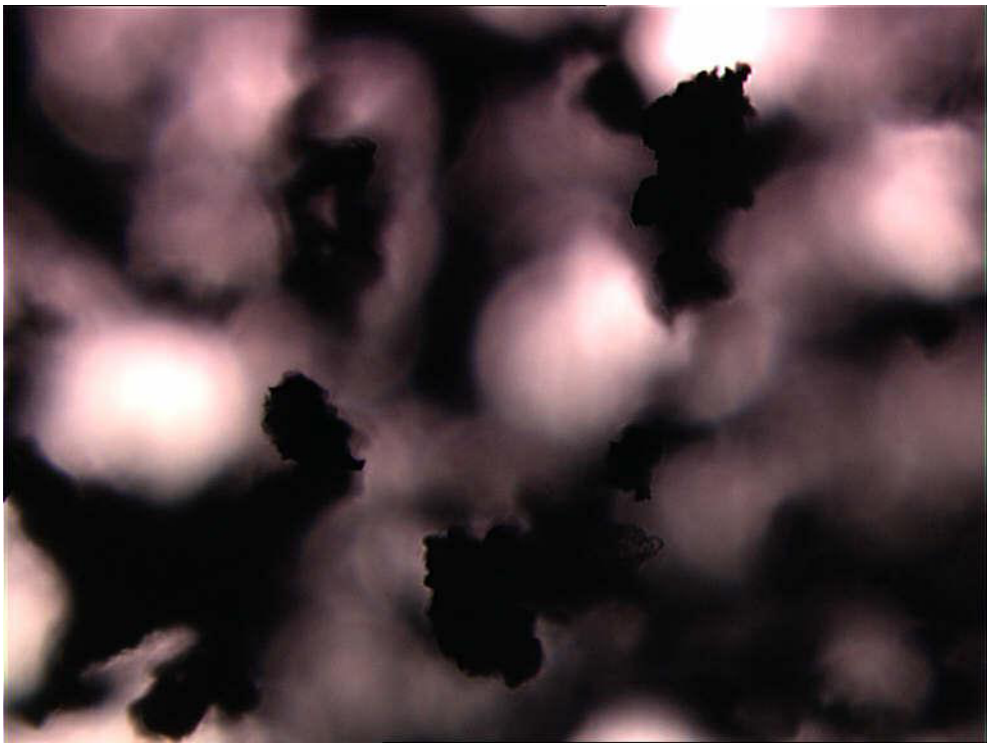

Figure 8.3.1 Top of the SEnsovant sensor coating on a glass substrate under a confocal laser microscope. The carbon based coating is highly porous, and every element acts as a light trap. The end result is a coating of very high absorption. The ends of carbon particles are in-focus, the outlines of the underlying layers can be seen out-of focus

8.4 Declaration of conformity CE

CE

We Hukseflux Thermal Sensors
of Elektronicaweg 25
2628 XG Delft
The Netherlands

in accordance with the following Directive:

2004/108/EC The Electromagnetic Compatibility Directive

hereby declare that:

Equipment: pyranometer/ radiometer/ heat flux sensor
Type: DR01 and DR02

are in conformity with the applicable requirements of the following documents

Emission: EN 61326-1 (2006)
Immunity: EN 61326-1 (2006)
Emission: EN 61000-3-2 (2006)
Emission: EN 61000-3-3 (1995) + A1 (2001) + A2 (2005)

I hereby declare that the equipment named above has been designed to comply with the relevant sections of the above referenced specifications and is in accordance with the requirements of the Directive.

Delft
September 2011

T: (+34) 96 816 2005
comercial@sensovant.com
www.sensovant.com

Avda. Benjamin Franklin, 28
Parque Tecnológico Valencia
46980 - PATERNA