LP PYRHE 16

1 Introduction

The pyrheliometer LP PYRHE 16 (First Class Pyrheliometer according to ISO 9060 classification) is an instrument for direct measurement of solar irradiance (Watt/m^2). The receiving surface must be positioned (via a solar tracker or else) perpendicularly to sun's rays. By using suitable diaphragms only the direct light reaches the surface of the sensor. According to WMO (Seventh edition 2008) and ISO 9069 regulations, the pyrheliometer has a field of view of 5°.

The pyrheliometer is produced in three versions:

LP PYRHE 16	PASSIVE
LP PYRHE 16 AC	ACTIVE with 4..20mA CURRENT output
LP PYRHE 16 AV	ACTIVE with 0..1V or 0..5V o 0..10V VOLTAGE output to be defined at the time of placing the order

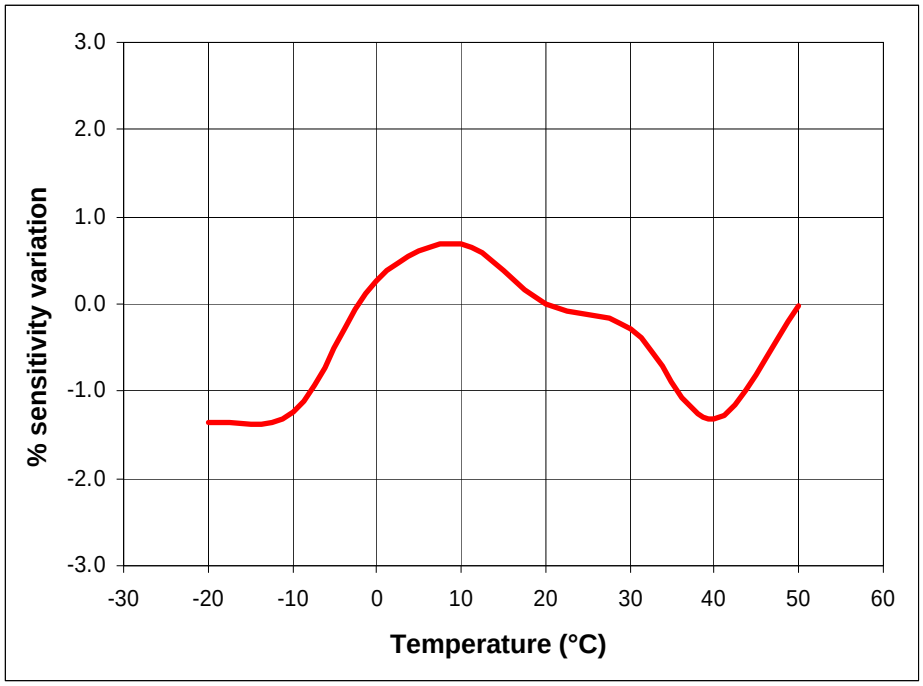
2 Operating Principle

The pyrheliometer LP PYRHE 16 is based on a new passive thermopile sensor. The sensitive surface of the thermopile is coated with a matt black paint, which makes the instrument not selective to the different wave lengths. The spectral range of the pyrheliometer is determined by the transmission of the quartz window, which function is to protect the sensor from dust and water. A special quartz allows to perform a 250nm-4000nm non-selective measurement.

The adopted sensor allows to have a response time lower than the requirements of the ISO9060 for the classification of first class pyrheliometers (the response time is under 9 seconds while the standard requires a response time lower than 20 seconds).

Radiant energy is absorbed by the blackened surface of the thermopile, thus creating a difference in temperature between the hot junction and the body of the pyrheliometer, which in this case acts as a cold junction. Through the Seebeck effect, the difference in temperature between hot and cold junction is converted into a Difference of Potential.

In order to reduce the variations of sensitivity depending on the temperature and to comply within the specifications requested to a secondary pyrheliometer, the LP PYRHE 16 is provided with a passive compensation circuit. Graph 1 shows the typical variation of sensitivity at different temperatures.



Graph 1: *% variation of sensitivity of the LP PYRHE 16 pyrheliometer compared to the sensitivity at 20 °C, in the temperature range from -20 to 50°C.*

Deviations are calculated starting from the sensitivity measured at 20°C.
The LP PYRHE 16 is a sealed instrument, for that reason a cartridge of Silica-gel crystals is provided to dry the air inside the instrument, in order to prevent condensation from forming on the quartz window of the instrument which would affect the performed measurements.

The angular field of view is 5° in accordance with WMO regulations and the slope angle is 1° (figure 1).

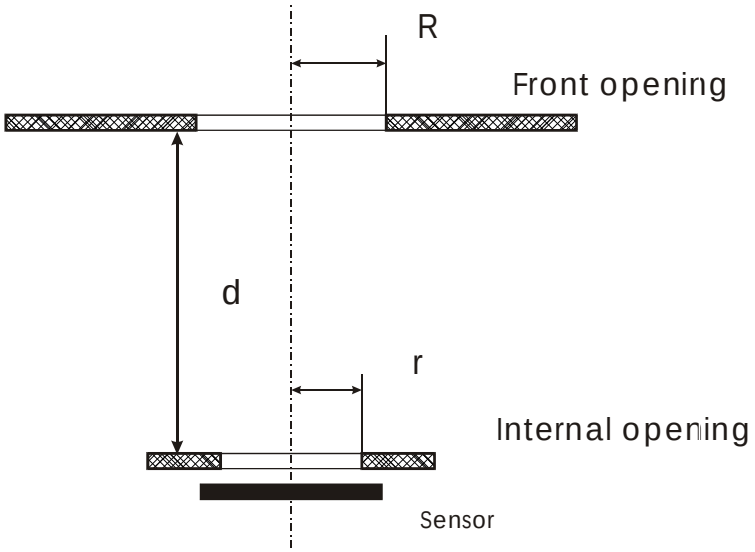


Fig.1: Field of view = 2 * arctan (R/d)

Slope angle = arctan ([R-r]/d)

In order to minimize the interference of stray light while reading the pyrheliometer, it is possible to put a hood.

For spectral measurements of direct solar radiance, which are useful for the determination of the optical thickness in the atmosphere, the pyrheliometer LP PYRHE 16 can be equipped with a kit consisting of an appropriate light shield (which allows monitoring of the filter holder wheel) plus a revolving filter holder wheel. The filter holder wheel is equipped with the filters below listed:

Filter Type	Cutoff wave length [nm]		Average transmission coefficient
	Lambda short waves	Lambda long waves	
OG 530	526	2900	0.92
RG 630	630	2900	0.92
RG 695	695	2900	0.92

It can be ordered separately as an accessory.
The pyrheliometer dimensions are shown in figure 2:

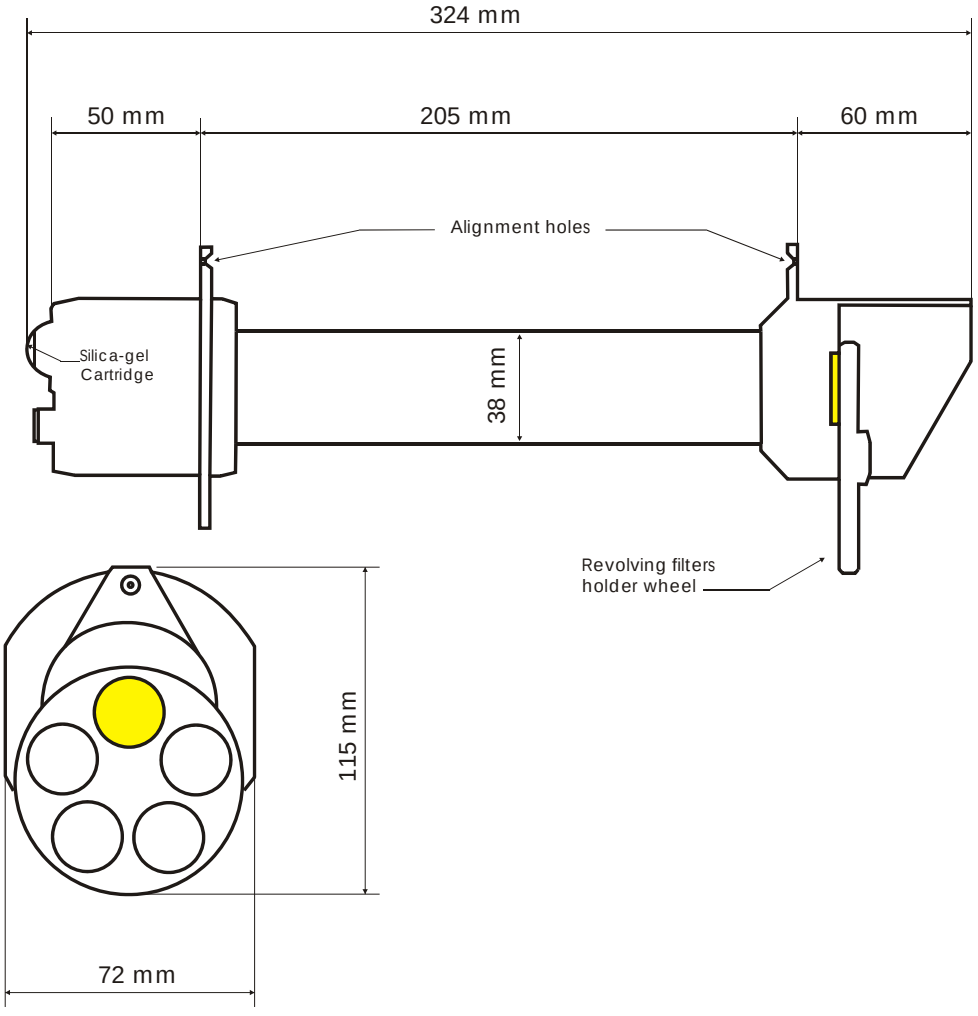


Fig. 2

3 Installing and assembling the pyrheliometer for the measurement of direct solar radiance:

Before installing the pyrheliometer, refill the cartrige which contains the silica-gel crystals. Silica-gel is used to absorb humidity inside the instrument and could lead to the formation of condensation on the internal wall of the quartz window, under particular climatic conditions, altering in this way the measurement. While refilling the silica-gel cartridge, avoid wetting it or touching it with your hands. The operations should to be performed in a dry environment (as far as possible) as follows:

1- Unscrew the silica-gel cartridge using a coin
2- Remove the perforated cap of the cartridge
3- Open the bag (supplied with the pyrheliometer) containing the silica-gel
4- Fill the cartridge with the silica-gel crystals
5- Close the cartridge with its own cap, making sure that the O-ring is correctly positioned
6- Screw the cartridge to the pyrheliometer body by means of a coin
7- Make sure the cartridge is screwed tightly (otherwise the duration of silica-gel crystal is reduced)
8- the pyrheliometer is ready for use

Figure 3 briefly explains the necessary steps to fill the cartridge with the silica-gel crystals.

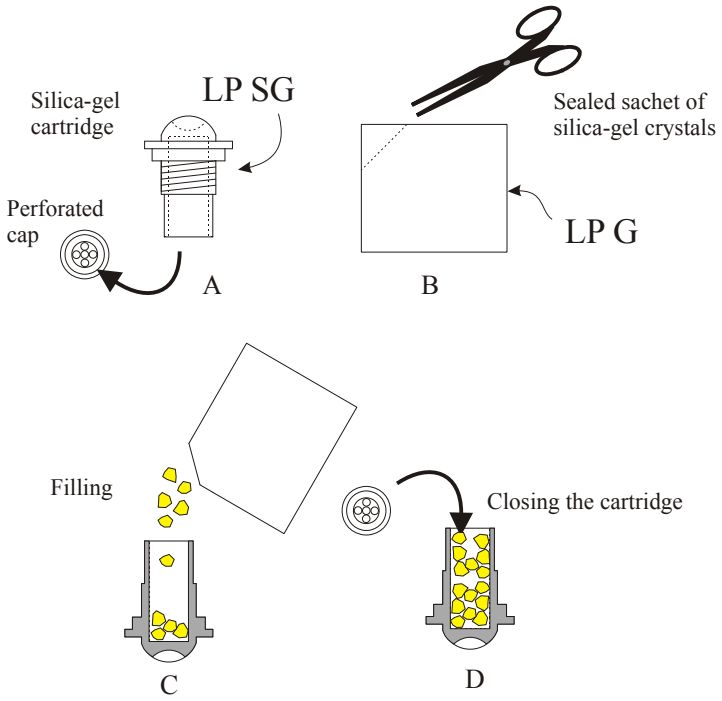


Fig. 3

- LP PYRHE 16 should be mounted in an easily reachable place to allow periodic cleaning of the quartz window and maintenance. At the same time you should avoid buildings, trees or obstructions of any kind intercepting the path of the sun during the day, all year round.

- For the automatic tracking of the pyrheliometer, the two holes present in the front and in the back of the flange can be used. In order to properly align the instrument, it is sufficient make sure that the sun beams that pass through the first hole (on the front flange of the pyrheliometer) reach the second hole (on the back flange).

4 Electric connections and requirements of the electronic readout device:

LP PYRHE 16 is produced in three versions: LP PYRHE 16, LP PYRHE 16 AC and LP PYRHE 16 AV.

- LP PYRHE 16 is the passive version and does not require power supply.
- LP PYRHE 16 AC, AV are active versions and they require power supply. The requested voltage is:
  8-30 VDC for the LP PYRHE 16 AC and for the LP PYRHE 16 AV with 0..1V and 0..5V output.
  14-30 VDC for the LP PYRHE 16 AV version with 0..10V output.
- All versions are provided with a 4-pole M12 output connector.
- The optional cable, with the connector at one end, is in UV-resistant PTFE, it is equipped with 3 wires plus shield, the correspondence between cable colors and connector pins is (figure 4):

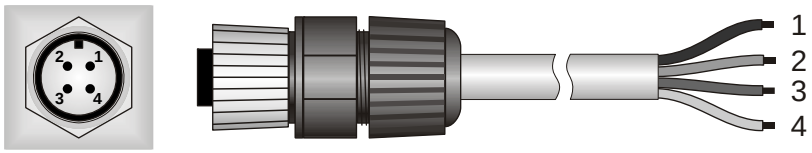


Fig. 4

LP PYRHE 16

Connector	Function	Color
4	Shield (⏚)	Black
1	Positive (+)	Red
2	Negative (-)	Blue
3	Housing (⏚)	White

LP PYRHE 16 AC

Connector	Function	Color
4	Shield (⏚)	Black
1	Positive (+)	Red
2	Negative (-)	Blue
3	Housing (⏚)	White

LP PYRHE 16 AV

Connector	Function	Color
4	Shield (⏚)	Black
1	(+) Vout	Red
2	(-) Vout and (-)Vcc	Blue
3	(+) Vcc	White

- LP PYRHE 16 has to be connected either to a millivoltmeter or to a data acquisition system. Typically, the pyrheliometer output signal does not exceed 20 mV. In order to better exploit the pyrheliometer features, the recommended resolution of the readout instrument is 1µV.

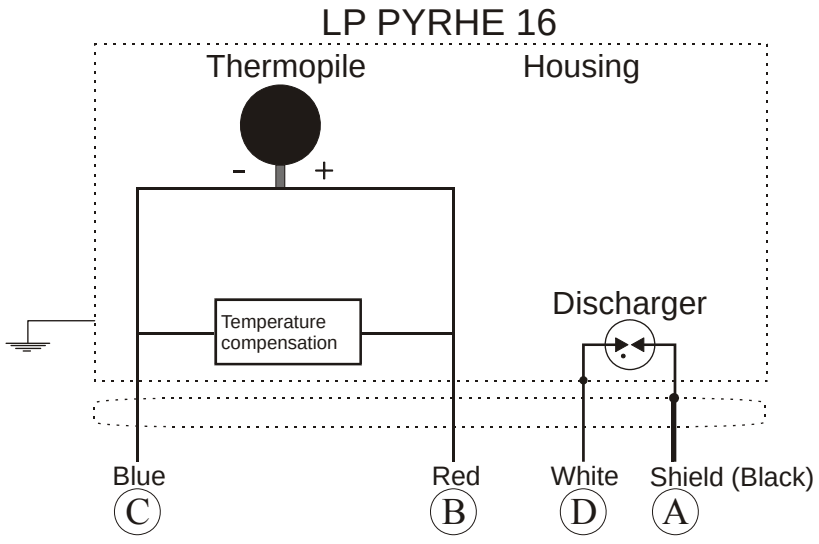


Fig. 5

An example of a connection to a reading device is shown in figure 6.

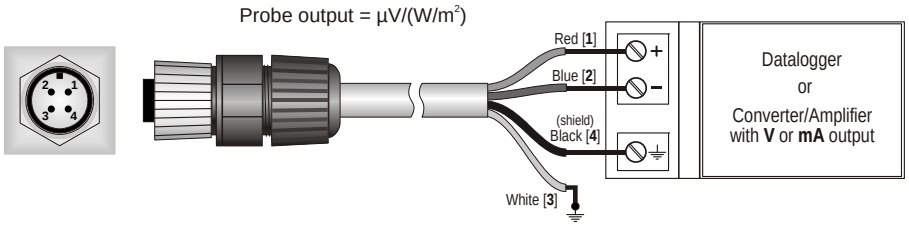


Fig. 6

- LP PYRHE 16 AC should be connected to a power supply device and to a multimeter according to the scheme below (figure 7); the load resistance for signal readout should be ≤ 500 Ω:

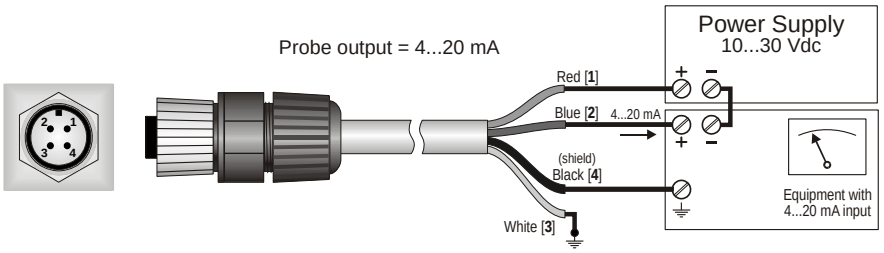


Fig. 7

- LP PYRHE 16 AV should be connected to a power supply device as well as to a multimeter according to the scheme below reported (figure 8); the load resistance for signal readout should be ≥ 100 KΩ:

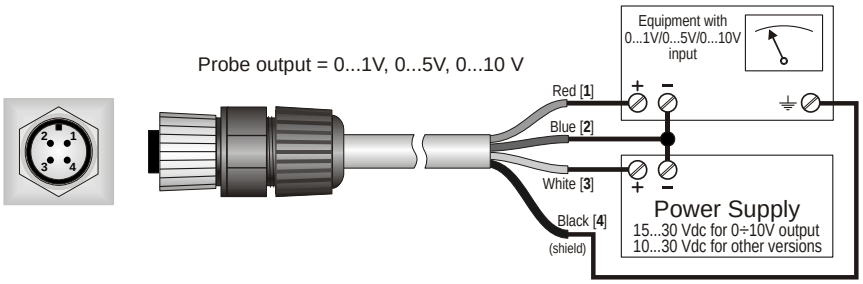


Fig. 8

5 Maintenance:

In order to grant high measurement accuracy, the quartz window should be always kept clean; consequently, the higher is the cleaning frequency, the more the measurements will be accurate. Cleaning can be performed with normal papers used for cleaning camera lenses and with some water, or alternatively with pure ETHIL alcohol. After cleaning with alcohol, the window must be washed with water only.

Because of the thermal shocks between day and night, it is possible that some condensation occurs on the window; in this case the performed readout will be strongly underestimated. In order to minimize condensation, a special cartridge filled with absorbent material is introduced inside the pyrheliometer: Silica-gel. The efficiency of silica-gel crystals decreases with time while they absorb humidity. When silica-gel crystals are efficient, their color is yellow, as they loose efficiency the color turns white/translucent; see instructions for replacement at paragraph 3. Typically, the duration of silica gel goes from 4 to 12 months according to the environmental conditions where the pyrheliometer operates.

6 Calibration and Measurements:

LP PYRHE 16

The sensitivity **S** of the pyrheliometer (or calibration factor) allows to determine direct irradiance by measuring a signal in Volts at the thermopile outputs. The **S** factor is given in $\mu V/(Wm^{-2})$.

- Once the difference of potential (DDP) has been measured at the ends of the probe, the E_e irradiance is obtained by applying the formula below:

$$E_e = DDP/S$$

where;

E_e: is the irradiance expressed in W/m^2,

DDP: is the difference of potential expressed in μV measured by the multimeter,

S: is the calibration factor in $\mu V/(W/m^2)$ shown on the pyrheliometer label (and mentioned in the calibration report).

LP PYRHE 16 AC

The sensitivity of the pyrheliometer is factory set so that, according to each version, we have :

4..20 mA = 0..2000 W/m^2

In order to obtain the direct irradiance value, once the current (I_{out}) absorbed by the instrument is known, the formula below should be applied:

$$Ee = 125 \cdot (I_{out} - 4mA)$$

where;

E_e: is the irradiance expressed in W/m^2,

I_{out}: is the mA current absorbed by the instrument

LP PYRHE 16 AV

The sensitivity of the pyrheliometer is factory-set so that, according to the chosen version, we have:

0..1 V = 0.. 2000 W/m^2
0..5 V = 0.. 2000 W/m^2
0..10 V = 0.. 2000 W/m^2

In order to obtain the irradiance value, once the instrument output voltage (V_{out}) is obtained, the formula below should be applied:

$$E_e = 2000 \cdot V_{out} \quad \text{for 0…1 V version}$$

$$E_e = 400 \cdot V_{out} \quad \text{for 0…5 V version}$$

$$E_e = 200 \cdot V_{out} \quad \text{for 0…10 V version}$$

where;
E_e: is the irradiance expressed in W/m^2,
V_{out}: is the output voltage (in Volts) measured with a Voltmeter

Each Pyrheliometer is factory calibrated and typified by its own calibration factor. To fully exploit all LP PYRHE 16 features it is recommended to perform an annual calibration check.

The equipment of the DeltaOhm Photo-Radiometry metrological laboratory allows to calibrate pyrheliometers according to WMO specifications and makes measurements referable to the international standards.

7 Technical Specifications:

Typical sensitivity:	10 µV/(W/m^2)	LP PYRHE 16
	4..20 mA (0-2000 W/m^2)	LP PYRHE 16 AC
	0..1,5,10V (0-2000 W/m^2)	LP PYRHE 16 AV

Impedance:	5 Ω ÷ 50 Ω
Measuring range:	0-2000 W/m^2
Field of view:	5° (slope 1°)
Spectral range: (dome transmission)	250 nm ÷ 4000 nm (50%) 280 nm ÷ 3800 nm (95%)
Working Temperature:	-40 °C ÷ 80 °C
Dimensions:	figure 1
Weight:	1.5 Kg

Technical Specifications according to ISO 9060

1- Response time: (95%)	<9 sec
2- Zero Off-set: Response to ambient temperature change of 5K/h:	<|±3| W/m^2
3a- long term instability: (1 year)	<|±1| %
3b- Non-linearity:	<|±0..5| %
3d- Spectral selectivity:	< |±1| %
3e- Response depending on Temperature:	< |±2| %
3f- Response depending on Tilt:	<|±0.5| %

8 Order codes

ORDER CODE	ITEM
LP PYRHE 16	First class Pyrheliometer according to ISO 9060. Equipped with: light shield, cartridge for silica-gel crystals, 3 refills, 4-pole M12 free plug and Calibration Report.
LP PYRHE 16 AC	First class Pyrheliometer according to ISO 9060. Equipped with: light shield, cartridge for silica-gel crystals, 3 refills, 4-pole M12 free plug and Calibration Report. Current signal output 4..20 mA.
LP PYRHE 16 AV	First class Pyrheliometer according to ISO 9060. Equipped with: light shield, cartridge for silica-gel crystals, 3 refills, 4-pole M12 free plug and Calibration Report. Voltage signal output 0..1Vdc, 0..5Vdc, 0..10Vdc, to be defined at the time of the order.
CPM AA 4.5	4-pole M12 free plug supplied with UV-resistant cable, L=10 meters.
CPM AA 4.10	4-pole M12 free plug supplied with UV-resistant cable, L=5 meters.
Kit 16.16	Kit consisting of revolving filter wheel (5positions) with 3 Shott filters (OG530, RG630, RG695), light shield and accessories to fix the wheel to the pyrheliometer.