OPERATING MANUAL

LPPIRG01

Pyrgeometer

EN

V3.0

Contents

1 Introduction

LPPIRG01 pyrgeometer measures the far infrared radiation (FIR). The measures are referred to radiations with wavelength greater than 4.5 µm.

The far infrared radiation derives from the measure of the thermopile output signal and from the knowledge of the instrument temperature. The temperature is measured with an NTC sensor integrated in the pyrgeometer housing.

The pyrgeometer can be used also for energy balance studies. In this case, besides another pyrgeometer which measures infrared radiation upwards, it is necessary an albedometer for measuring the short wavelengths radiation (<3 µm).

The various models are distinguished by the type of output available:

	Output	
Model	**Digital RS485 Modbus-RTU**	**Analog**
LPPIRG01	--	mV
LPPIRG01S	√	--

The pyrgeometer is factory calibrated and supplied with a calibration report. The calibration is carried out outdoors, for comparison with a reference standard pyrgeometer calibrated at WRC (World Radiation Center). The two instruments are kept outdoors for at least one night in the presence of clear sky. The data acquired by a data logger are then processed to obtain the calibration factor.

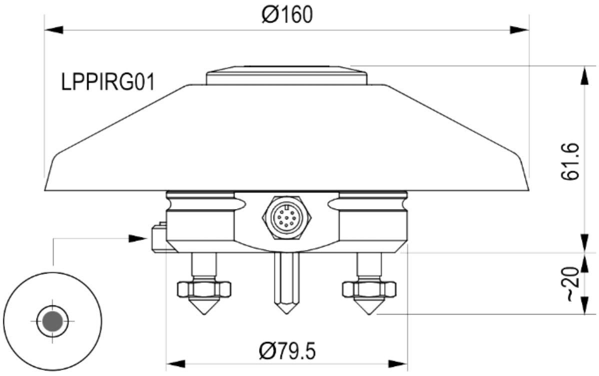
2 Technical specifications

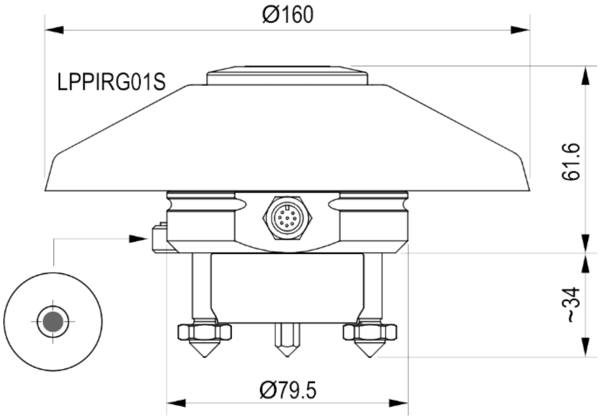
Sensor	Thermopile
Typical sensitivity	5…10 μV/Wm^{-2}
Impedance	33…45 Ω
Measuring range	-300…+300 W/m^2
Viewing angle	160°
Spectral range (50%)	5.5…45 μm
Operating temperature	-40÷80 °C
Output LPPIRG01 LPPIRG01S	passive in mV RS485 Modbus-RTU
Power supply LPPIRG01 LPPIRG01S	No power required 5…30 Vdc
Consumption LPPIRG01S	2 mA @ 24 Vdc
Connection	8-pole M12
Weight	0.9 kg approx.
Operating conditions	-40…+80 °C / 0…100 %RH / Max. altitude 6000 m
Bubble level accuracy	< 0.1°
Protection degree	IP 67
Materials	Housing: anodized aluminium Screen: ASA Sensitive area window: silicon
MTBF	> 10 years

Technical Specifications According to ISO 9060:2018

Response time (95%)	< 28 s
Zero offset (type B) a) response to a 5 K/h change in ambient temperature	<|±4|W/m^2
Long-term instability (1 year)	<|±1.5| %
Non-linearity	<|±1| %
Spectral selectivity	< |±5| %
Temperature response	< 3 %
Tilt response	<|±2| %

Dimensions (mm)





3 Measuring principle

The pyrgeometer is based on a thermopile sensor. The thermopile sensitive surface is coated with a black matt paint, which allows the pyrgeometer not to be selective at different wavelengths.

Silicon is transparent to wavelengths longer than 1.1 μm; therefore, a filter is deposited on the inside of the window to block the radiation up to 4.5-5 μm.

The silicon external surface, which is exposed to weathering, is protected by a scratch-resistant coating (DLC) to ensure strength and durability in all weather conditions. The scratch-resistant coating offers the advantage that the surface can be cleaned without the danger of scratching the window. The transmission of the silicon window versus wavelength change is shown below.

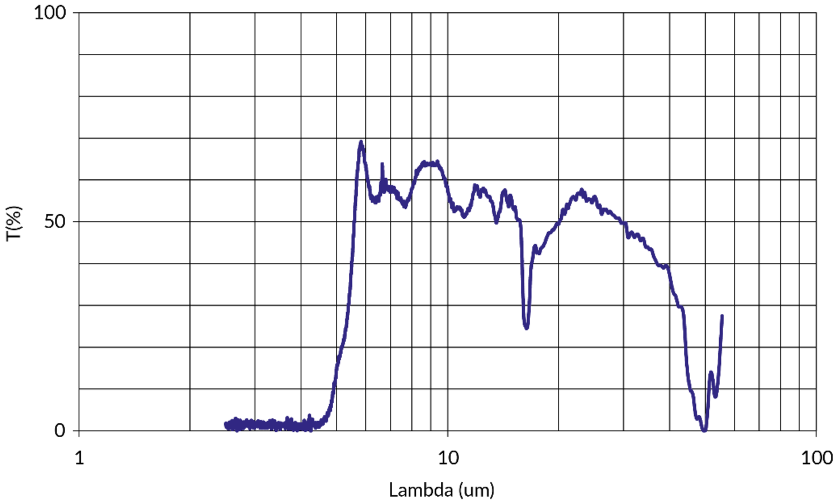


Fig. 3.1: pyrgeometer spectral range

Radiant energy is absorbed/radiated by the blackened thermopile surface, thus creating a difference of temperature between the center of the thermopile (hot junction) and the pyrgeometer body (cold junction). Thanks to the Seebeck effect, the difference of temperature between hot and cold junction is converted into a difference of potential.

If the pyrgeometer temperature is higher than the radiant temperature of the portion of sky or earth framed by the pyrgeometer itself, the thermopile will irradiate energy and the output signal will be negative (typical situation is clear sky); vice versa, if the pyrgeometer temperature is lower than that of the portion of sky or earth framed, the signal will be positive (typical situation is cloudy sky).

For the calculation of the infrared irradiance $E_{FIR}\downarrow$, besides the thermopile output signal, it is necessary to know the pyrgeometer temperature T_B, as reported in the following formula:

$$\mathbf{E_{FIR}\downarrow = E_{TERM} + \sigma T_B^4}$$

Where:

- **E_{TERM}** = net irradiance (difference between the infrared irradiance reaching the pyrgeometer and the emission of the pyrgeometer itself) in W/m^2 measured by the pyrgeometer.
- **σ** = Stefan-Boltzmann constant (5.6704x10^{-8} Wm^{-2}K^{-4}).
- **T_B** = pyrgeometer temperature in K (Kelvin).

The second term of the formula is the radiation emitted by an object, assumed to have emissivity ε=1, at temperature T_B.

4 Installation

Before installing the pyrgeometer, refill the cartridge containing silica-gel crystals. Silica-gel absorbs humidity inside the instrument and prevents, in particular climatic conditions, condensation on the internal surface of the silicon window and measurement alteration.

Do not touch the silica gel crystals with your hands while refilling the cartridge. Carry out the following instructions in an environment as drier as possible:

1. Loosen the three screws that fix the white shade disk.
2. Unscrew the silica gel cartridge using a coin.
3. Remove the cartridge perforated cap.
4. Open the sachet containing silica gel (supplied with the pyrgeometer).
5. Fill the cartridge with the silica gel crystals.
6. Close the cartridge with its own cap, paying attention that the sealing O-ring be properly positioned.
7. Screw the cartridge to the pyrgeometer body using a coin.
8. <u>Check that the cartridge is screwed tightly</u> (if not, silica gel life will be reduced).
9. Position the shade disk and screw it to the pyrgeometer housing.
10. The pyrgeometer is ready for use.

The figure below shows the operations necessary to fill the cartridge with the silica gel crystals.

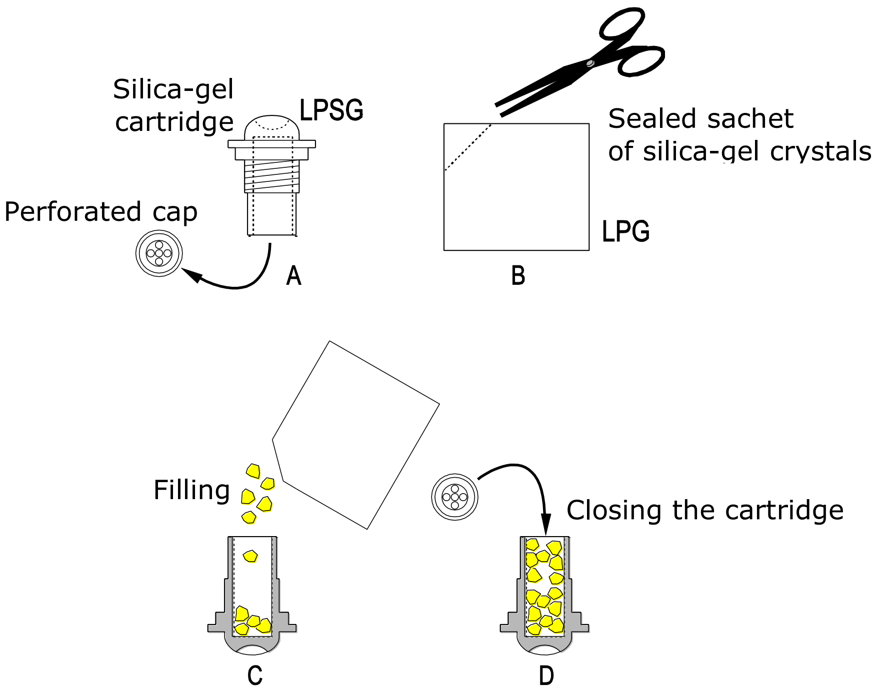


Fig. 4.1: filling the silica-gel cartridge

- The pyrgeometer must be mounted in an easy-to-reach location in order to clean the silicon window regularly. At the same time, make sure that no buildings, constructions, trees or obstructions exceed the horizontal plane where the pyrgeometer lies. If this is not possible, select a site where obstructions do not exceed 10°.
- In compliance with ISO TR9901 standard and WMO recommendations, if the pyrgeometer is used without the solar radiation protection screen, it must be positioned so that the connector points to the North Pole, if the instrument is used in the Northern Hemisphere, and to the South Pole, if used in the Southern Hemisphere. In any case, it is better to follow this recommendation even when the screen is used.
- For fixing, use the M5 (32 mm interaxis) or M8 (65 mm interaxis) holes on the bottom of the pyrgeometer The 65 mm interaxis holes can alternatively be used as thru-holes to fix the pyrgeometer from above with M5 screws (in this case, remove the shade disk to access the holes and reposition it after mounting). For an accurate horizontal positioning, adjust the height of the two lower feet with hex ring nut, using the bubble level integrated in the pyrgeometer.
- It is preferable to thermally insulate the pyrgeometer from its mounting bracket, while at the same time ensuring that there is good electrical contact to ground.

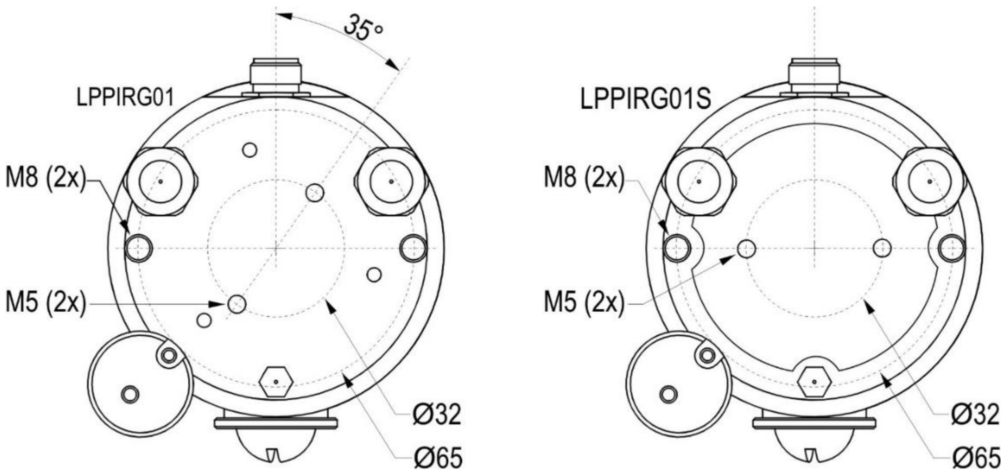


Fig. 4.2: fixing holes

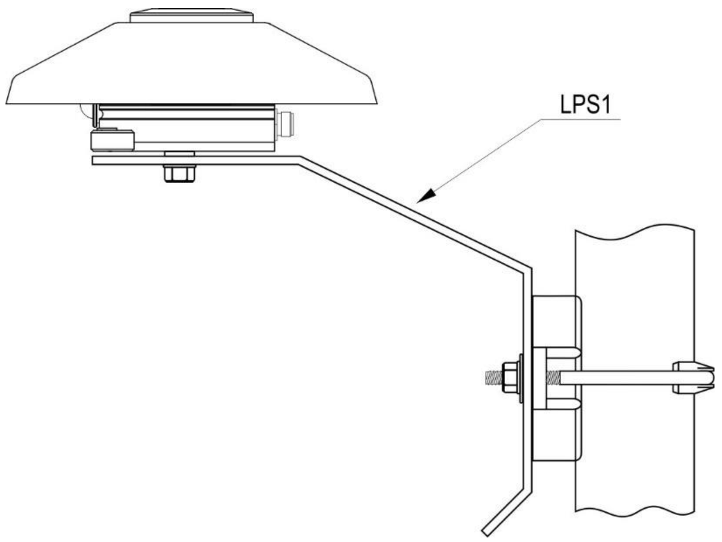


Fig. 4.3: Optional LPS1 bracket for mast

4.1 Electrical connections

Warning!

The metallic housing of the pyrgeometer should preferably be grounded (earthed) locally. Do not connect the wire of the cable corresponding to the housing to ground, unless it is not possible to ground the pyrgeometer metallic housing locally via the support mast.

Internally there are surge protection devices connected to the housing. Grounding the housing allows the correct protection functionality of the devices.

LPPIRG01 connector pinout:

Pyrgeometer male connector (external view)		Function	CPM12AA8PG... wire color
	1	+Vout	Red
	2	-Vout	Blue
	3	Housing	White
	4	NTC	Green
	5	Cable shield	Brown
	6	NC	--
	7	NC	--
	8	NTC	Black

LPPIRG01S connector pinout:

Pyrgeometer male connector (external view)		Function	CPM12-8D... wire color
	1	GND (Power supply negative)	Blue
	2	+Vdc (Power supply positive)	Red
	3	NC	--
	4	DATA – (RS485)	Brown
	5	DATA + (RS485)	White
	6	Housing / Cable shield	Black
	7	NC	--
	8	NC	--

LPPIRG01 connections:

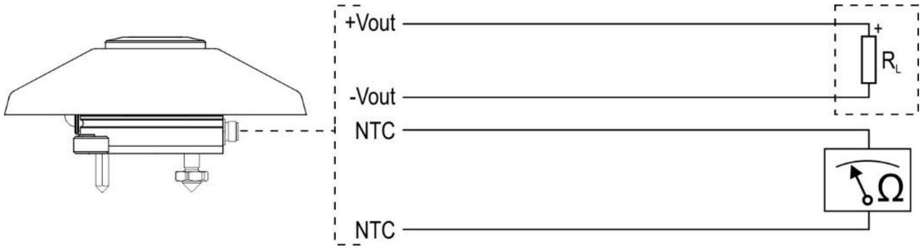


Fig. 4.4: LPPIRG01 connection diagram

The pyrgeometer does not require power supply. The typical output impedance of the sensor is <50 Ω.

The output signal typically does not exceed a few mV. The recommended resolution of the reading instrument is 1 μV.

Connect the cable shield to the ground of the reading instrument.

LPPIRG01S connections:

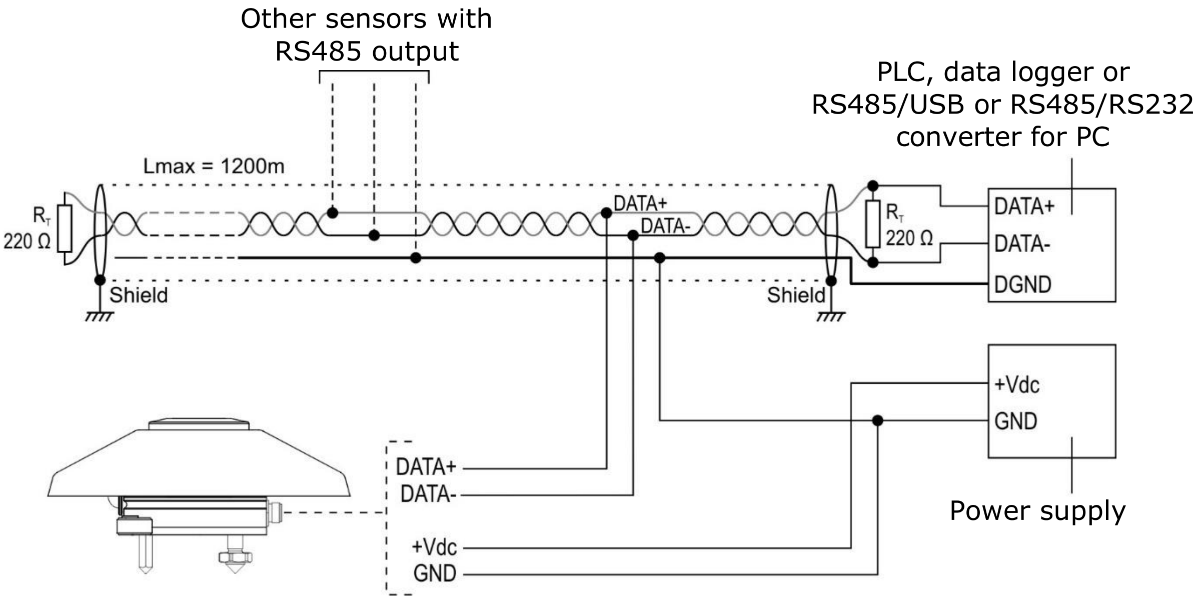


Fig. 4.5: LPPIRG01S connection diagram

RS485 output:

The RS485 output is not isolated. Before connecting the pyrgeometer to the RS485 network, set the address and the communication parameters, if different from the factory preset (see "Configuration" chapter).

5 LPPIRG01S configuration

Before connecting the pyrgeometer to the RS485 network, an address must be assigned and the communication parameters must be set, if different from the factory preset.

By default, the instrument has Modbus address **1** and communication parameters 19200, 8E1.

Connection to PC:

To connect the pyrgeometer to a PC USB port, to check or change the configuration, the **CP24** optional cable can be used, which also allows the pyrgeometer to be powered via the USB port.

To use the CP24 cable, the related USB drivers must be installed in the PC.

Alternatively, it is possible to use a standard RS485/USB or RS485/RS232 converter, powering the pyrgeometer separately.

Procedure:

1. Connect the pyrgeometer to the PC and start a standard serial communication program.
2. In the serial communication program, set the Baud Rate 57600, the parameters 8N2 and the COM port number to which the pyrgeometer is connected.
3. Power the pyrgeometer (or power cycle if already powered) and send the command **@** within 10 seconds from the instrument power on (the pyrgeometer replies **&|** if the command @ is recognized).

   Note: if the CP24 cable is used, to power cycle the pyrgeometer, disconnect the cable for a few seconds from the PC USB port, then reconnect it.
4. Send the command **CAL USER ON** to enable the configuration change. The command CAL USER ON is not required only for reading the settings.
5. Send the commands described in the table below.

The command CAL USER ON is automatically disabled after a few minutes of inactivity. The command CAL USER ON can be disabled immediately by sending the command CAL EXIT.

Command	Reply	Description
CMAn	&|	Sets the Modbus-RTU address (1…247) to n. Default=1
RMA	*Address*	Reads the Modbus-RTU address.
CMBn	&|	Sets the Baud Rate: ▪ 9600 if n=0 ▪ 19200 if n=1 (*default*) ▪ 38400 if n=2 ▪ 57600 if n=3 ▪ 115200 if n=4
RMB	*Baud Rate index*	Reads Baud Rate setting.
CMPn	&|	Sets parity and stop bits (data bits = 8 fixed): ▪ 8N1 if n=0 ▪ 8N2 se n=1 ▪ 8E1 if n=2 (*default*) ▪ 8E2 se n=3 ▪ 8O1 if n=4 ▪ 8O2 se n=5

Command	Reply	Description
RMP	*Parity and stop bits index*	Reads the setting of parity and stop bits.
CMWn	&|	Sets waiting time after transmission with Modbus-RTU protocol: ▪ Immediate reception if n=0 (violates protocol) ▪ Waiting 3.5 characters if n=1 (respects protocol) *Default* : Waiting 3.5 characters (n=1)
RMW	*Waiting time index*	Reads the setting of waiting time after transmission with Modbus-RTU protocol.

6 Modbus-RTU protocol (LPPIRG01S)

The Modbus-RTU protocol is active after a few seconds from the sensor power on.

Below is the list of registers.

Input Registers:

Address	Description	Format
0	Temperature in °C (x10)	16-bit Integer
1	Temperature in °F (x10)	16-bit Integer
2	Irradiance in W/m^2	16-bit Integer
3	Status register: bit0=1 ⇒ irradiance measurement error bit2=1 ⇒ configuration data error bit3=1 ⇒ program memory error	16-bit Integer
4	Average values of the last 4 irradiance measurements	16-bit Integer
5	Signal generated by the sensor in μV/10 (e.g., 816 means 8160 μV, the resolution is 10 μV)	16-bit Integer

7 Measurement with analog output (LPPIRG01)

It is necessary to measure the output signal in mV and the resistance of the internal NTC temperature sensor.

Each pyrgeometer is distinguished by its own sensitivity (or calibration factor) ***S*** expressed in μV/(Wm^{-2}), shown in the label on the pyrgeometer and in the calibration report.

The irradiance $\mathbf{E_{FIR}}\downarrow$ in W/m^2 is obtained by measuring with a multimeter the difference of potential ***DDP*** at the ends of the sensor and applying the following formulas:

$$\mathbf{E_{FIR}\downarrow = (DDP / S) + \sigma T_B^4}$$

where:

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

S is the sensitivity of the pyrgeometer expressed in μV/(Wm^{-2}).

σ is the Stefan-Boltzmann constant (5.6704x10^{-8} Wm^{-2}K^{-4}).

$\mathbf{T_B}$ is the pyrgeometer temperature in K (Kelvin), obtained by the measurement of the NTC resistance.

The pyrgeometer temperature $\mathbf{T_B}$ (K) is obtained by measuring the NTC resistance $\mathbf{R_{NTC}}$ (Ω) and applying the following formula:

$$\frac{1}{\mathbf{T_B}} = \mathbf{a} + \mathbf{b}\log(\mathbf{R_{NTC}}) + \mathbf{c}\log(\mathbf{R_{NTC}})^3$$

Where:

a = 10297.2 x 10^{-7}

b = 2390.6 x 10^{-7}

c = 1.5677 x 10^{-7}

Table 7.1 indicates the correspondence between $\mathbf{T_B}$ and $\mathbf{R_{NTC}}$ for temperature values between -25 °C and +58 °C. To obtain the temperature value in Kelvin, add 273.15 to the temperature value in degrees Celsius in the table.

TAB. 7.1: correspondence between pyrgeometer temperature and NTC resistance

T_B (°C)	R_{NTC} (Ω)	T_B (°C)	R_{NTC} (Ω)	T_B (°C)	R_{NTC} (Ω)
-25	103700	3	25740	31	7880
-24	98240	4	24590	32	7579
-23	93110	5	23500	33	7291
-22	88280	6	22470	34	7016
-21	83730	7	21480	35	6752
-20	79440	8	20550	36	6499
-19	75390	9	19660	37	6258
-18	71580	10	18810	38	6026
-17	67970	11	18000	39	5804
-16	64570	12	17240	40	5592
-15	61360	13	16500	41	5388
-14	58320	14	15810	42	5193
-13	55450	15	15150	43	5006
-12	52740	16	14520	44	4827
-11	50180	17	13910	45	4655
-10	47750	18	13340	46	4489
-9	45460	19	12790	47	4331
-8	43290	20	12270	48	4179
-7	41230	21	11770	49	4033
-6	39290	22	11300	50	3893
-5	37440	23	10850	51	3758
-4	35690	24	10410	52	3629
-3	34040	25	10000	53	3505
-2	32470	26	9605	54	3386
-1	30980	27	9228	55	3386
0	29560	28	8868	56	3271
1	28220	29	8524	57	3161
2	26950	30	8195	58	3055

8 Maintenance

In order to grant measurements high accuracy, it is important to keep the silicon window clean. The higher the frequency of cleaning, the better the accuracy of measurements.

You can wash it using water and standard papers for lens. If necessary, use pure ETHYL alcohol. After using alcohol, clean again the silicon window with water only.

To minimize condensation and keep measurements accurate, a cartridge of desiccant silica-gel is provided inside the pyrgeometer to absorb moisture. The efficiency of silica-gel decreases over time while absorbing humidity. Silica-gel crystals are efficient when their color is **yellow**, while they turn **white/translucent** as soon as they lose their efficiency. To replace silica-gel crystals, see chapter 4. Silica-gel typical lifetime goes from 2 to 6 months depending on the environment where the pyrgeometer operates.

Hail of particular intensity/size may damage the silicon window; therefore, it is recommended to check the status of the window after an intense storm with hail.

To exploit all the pyrgeometer features, it is highly recommended that the calibration be checked annually.

9 Safety instructions

The pyrgeometer proper operation and operating safety can be ensured only in the climatic conditions specified in this manual and if all standard safety measures as well as the specific measures described in this manual are followed.

Do not use the instruments in places where there are:

- Corrosive or flammable gases.
- Direct vibrations or shocks to the instrument.
- High-intensity electromagnetic fields, static electricity.

User obligations

The instrument operator shall follow the directives and regulations below that refer to the treatment of dangerous materials:

- EU directives on workplace safety.
- National law regulations on workplace safety.
- Accident prevention regulations.

10 Accessories ordering codes

The pyrgeometer is supplied with solar radiation protection screen, sylica-gel cartridge, 2 spare sachets, bubble level, M12 female free connector (only if the optional cable is not ordered) and calibration report.

Cables and fixing accessories must be ordered separately.

Fixing accessories

LPS1	Fixing bracket for Ø 30…50 mm mast. Installation on horizontal or vertical mast.

Installation cables

CPM12AA8PG…	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 5 m (CPM12AA8PG.5) or 10 m (CPM12AA8PG.10). **For LPPIRG01.**
CPM12-8D…	Cable with 8-pole M12 connector on one end, open wires on the other end. Length 5 m (CPM12-8D.5) or 10 m (CPM12-8D.10). **For LPPIRG01S.**

PC connecting cables

CP24	PC connecting cable for the configuration of the pyrgeometer. With built-in RS485/USB converter. 8-pole M12 connector on sensor side and A-type USB connector on PC side. **For LPPIRG01S**.

Spare parts

LPSP1	UV-resistant solar radiation protection screen.
LPG	Silica-gel (5 sachets).
LPSG	Cartridge to contain desiccant silica-gel crystals, complete with O-ring and cap.

WARRANTY

The manufacturer is required to respond to the "factory warranty" only in those cases provided by Legislative Decree 6 September 2005 - n. 206. Each instrument is sold after rigorous inspections; if any manufacturing defect is found, it is necessary to contact the distributor where the instrument was purchased from. During the warranty period (24 months from the date of invoice) any manufacturing defects found will be repaired free of charge. Misuse, wear, neglect, lack or inefficient maintenance as well as theft and damage during transport are excluded. Warranty does not apply if changes, tampering or unauthorized repairs are made on the product. Solutions, probes, electrodes and microphones are not guaranteed as the improper use, even for a few minutes, may cause irreparable damages.
The manufacturer repairs the products that show defects of construction in accordance with the terms and conditions of warranty included in the manual of the product. For any dispute, the competent court is the Court of Padua. The Italian law and the "Convention on Contracts for the International Sales of Goods" apply.

TECHNICAL INFORMATION

The quality level of our instruments is the result of the continuous product development. This may lead to differences between the information reported in the manual and the instrument you have purchased.
We reserve the right to change technical specifications and dimensions to fit the product requirements without prior notice.

DISPOSAL INFORMATION

Electrical and electronic equipment marked with specific symbol in compliance with 2012/19/EU Directive must be disposed of separately from household waste. European users can hand them over to the dealer or to the manufacturer when purchasing a new electrical and electronic equipment, or to a WEEE collection point designated by local authorities. Illegal disposal is punished by law.

Disposing of electrical and electronic equipment separately from normal waste helps to preserve natural resources and allows materials to be recycled in an environmentally friendly way without risks to human health.

CE RoHS

senseca.com

Senseca Italy S.r.l.
Via Marconi, 5
35030 Selvazzano Dentro (PD)
ITALY
info@senseca.com