

LPNET14

1 Introduction

LPNET14 is a 4-component net-radiometer for the measurement of the net radiation between 0.3 μm and 45 μm .

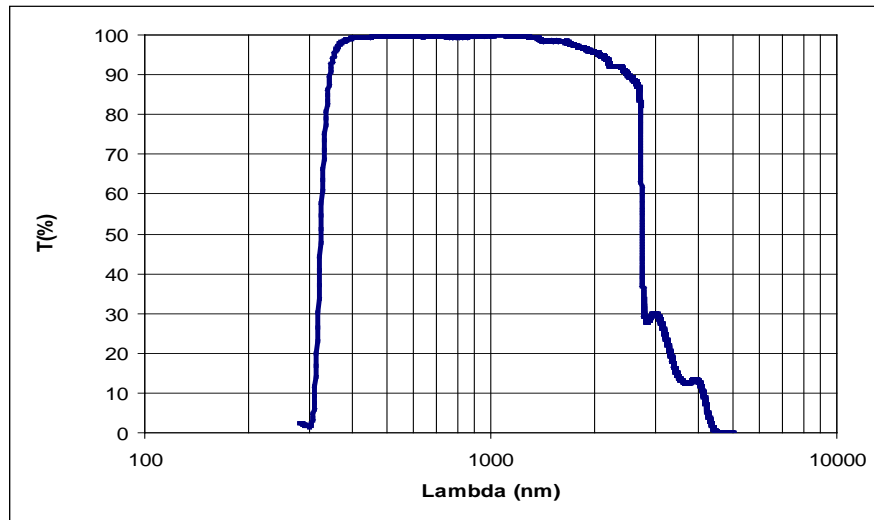
The net-radiometer consists of two pyranometers (one for the measurement of the global radiation $E_{\text{sw}\downarrow}$ and the other one for the measurement of the reflected solar radiation $E_{\text{sw}\uparrow}$) and a pair of pyrgeometers (one for the measurement of the infrared radiation emitted by the sky $E_{\text{fir}\downarrow}$ and the other one for the infrared emitted by the ground surface $E_{\text{fir}\uparrow}$).

The LPNET14 is equipped with a temperature sensor (NTC). The measurement of the temperature is needed for the measurement with the two pyrgeometers, in fact, the far infrared is derived by measuring the thermopile output and by the knowledge of the instrument's temperature.

The net radiometer is suitable for outdoor use in all weather conditions and requires little maintenance.

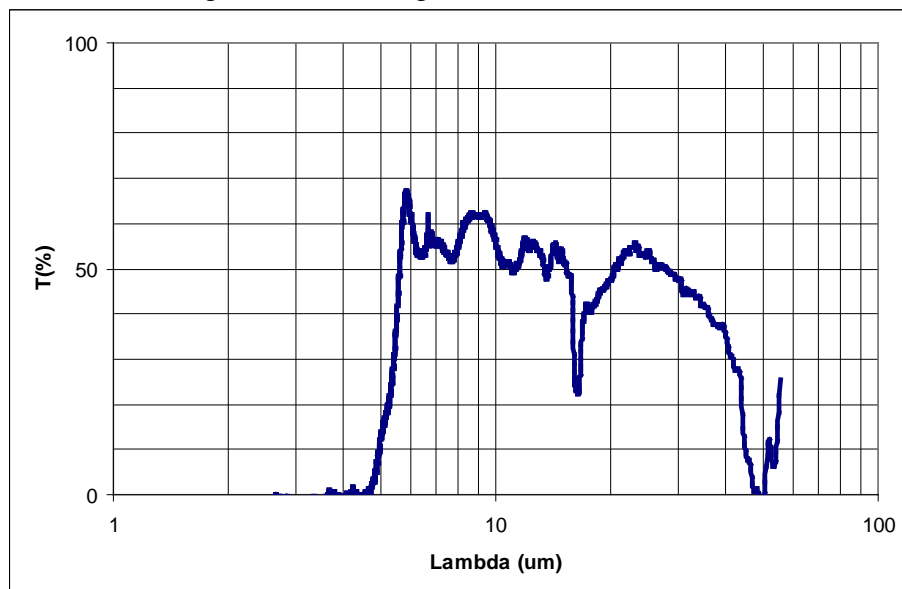
2 Working principle

The pyranometers that make up the LPNET14 measure the radiation for wave lengths between 0.3 μm and 3.0 μm , while the pyrgeometers measure the irradiance in the spectral range between 5 μm and 45 μm . The pyranometers are based on a thermopile sensor which sensitive surface is covered by a matt black paint so to allow the instrument not to be selective at various wavelengths. The pyranometer spectral range is determined by the transmittance of the two glass domes type K (See fig. 1). Radiant energy is absorbed by the thermopile black surface, creating a difference of temperature between the centre of the thermopile (hot junction) and the pyranometer body (cold junction). Thanks to the Seebeck effect, the difference of temperature between hot and cold junction is converted into a Difference of Potential.



Graphic 1: Relative spectral response of the Delta OHM pyranometers.

Also the pyrgeometers are based on a thermopile. In this case, to protect the thermopile, silicon discs are used. Silicon is transparent to wavelengths longer than 1.1 μm therefore on the inside of the window there is a filter to block radiation up to 4.5- 5 μm . The silicon external surface, which is exposed to weathering, is coated with a scratch-resistant coating (DLC) to ensure strength and durability in all weather conditions. The anti-scratch coating offers the advantage of cleaning the surface without risk of scratching the window. Graphic 2 reports the transmission of the silicon window according to the wavelength variation:



Graphic 2: Transmission of the silicon window.

Radiant energy is absorbed / radiated from the surface of the blackened thermopile, creating a temperature difference between the centre of the thermopile (hot junction) and the body of pyrgeometer (cold junction). The temperature difference between hot and cold junction is converted into Potential Difference thanks to the Seebeck effect. If the pyrgeometer temperature is higher than the radiant temperature of the portion of sky framed by the pyrgeometer, the thermopile will irradiate energy and the output signal will be negative (typical situation of clear sky) vice versa if the pyrgeometer temperature is lower than that portion of sky framed, the signal will be positive (typical situation of cloudy sky). Therefore, for the calculation of the ground infrared ($E_{FIR\downarrow}$), besides the thermopile output signal, is necessary to know the T temperature of the pyrgeometer, as reported under the formula 1:

$$E_{FIR\downarrow} = E_{term.} + \sigma T_B^4 \quad 1$$

Where:

$E_{term.}$ = net radiation (positive or negative), measured by the thermopile [$W\ m^{-2}$], the value is calculated by the sensitivity of the instrument C [$\mu V / (W\ m^{-2})$] and by the output signal (U_{emf}) from formula 2;

$$E_{term.} = \frac{U_{emf}}{C} \quad 2$$

σ = Stefan-Boltzmann constant ($5.6704 \times 10^{-8}\ W\ m^{-2}\ K^{-4}$);

T_B = pyrgeometer temperature (K), obtained by the reading of the NTC (10k Ω) resistance. In Table 2 (in the following pages) is reported the resistance value according to the temperature for values included between $-25^\circ C$ and $+58^\circ C$.

The first term of the formula 1 represent the net radiation, that is to say the difference between ground infrared radiation and the pyrgeometer emission, while the second term is the radiation emitted by an object (taken with submissiveness $\epsilon=1$) at T_B temperature.

3 Installation and mounting of the net-radiometer for the infrared radiation measure:

Before installing the net-radiometer you need to load the lower compartment with two cartridges containing silica gel crystals. The silica gel has the function of absorbing humidity present inside the instrument; in particular, climatic conditions this humidity can lead to condensation on the inner surface of the silicon window. While loading silica gel crystals, avoid touching it with wet hands. The operations to perform (as much as possible) in a dry place are:

- 1- unscrew the six screws that fix the inner cap of the net-radiometer (fig.3).
- 2- remove (if present) the old cartridge and the marker
- 3- open the envelope containing the silica gel and the marker, trim the marker to match the R.H. indicator 10% (make sure that the dimensions are appropriate to the salts compartment)
- 4- insert the cartridge in the salts-compartment
- 5- insert the marker so that it can easily be checked without opening the salts compartment
- 6- tighten the six screws on the lid, make sure that the seal is positioned correctly.
- 7- the net-radiometer is ready for use

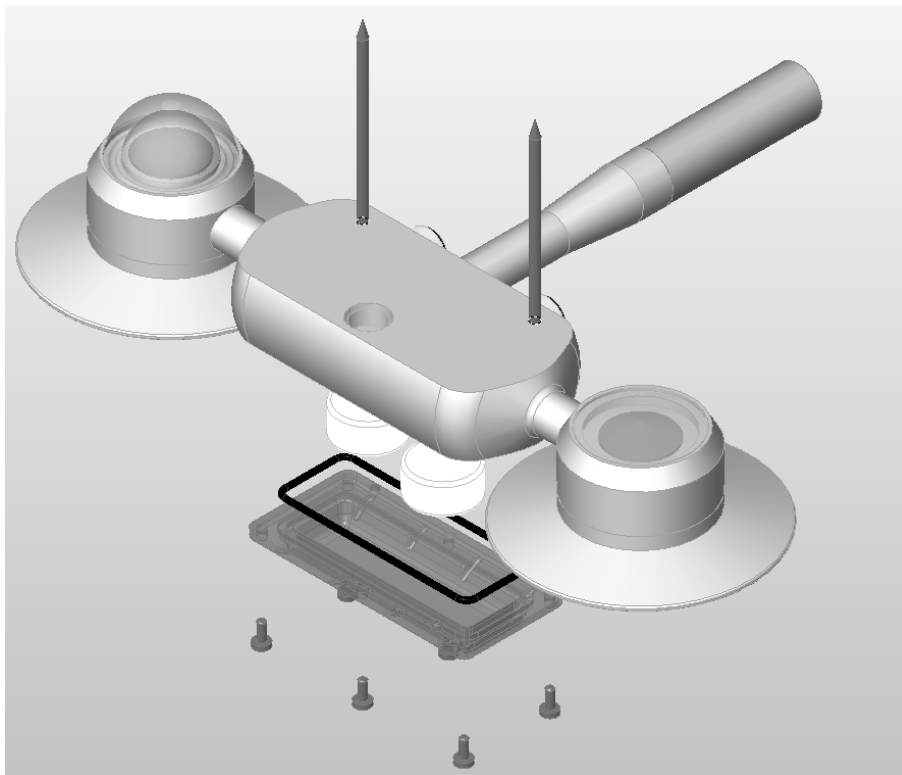


Fig. 3

- The LPNET14 has to be installed in a location easily accessible for periodic cleaning of the silicon window. At the same time, you should avoid buildings, trees or obstacles of any kind exceed the horizontal plane on which lies the - 5 - instrument. In case this is not possible it is advisable to choose a location where the obstacles are lower than 10° .
- Usually the instrument is placed so that the cable comes out from the side of the NORTH pole, when it is used in the NORTHERN hemisphere; from the side of the SOUTH pole when it is used in the SOUTHERN hemisphere, according to the standard ISO TR9901 and other WMO recommendations. In any case, it is preferable to comply with these recommendations also when the screen is used.
- For an accurate horizontal positioning, the LPNET14 has to be fixed on a support pole by using the fixing bracket. (Fig.4).

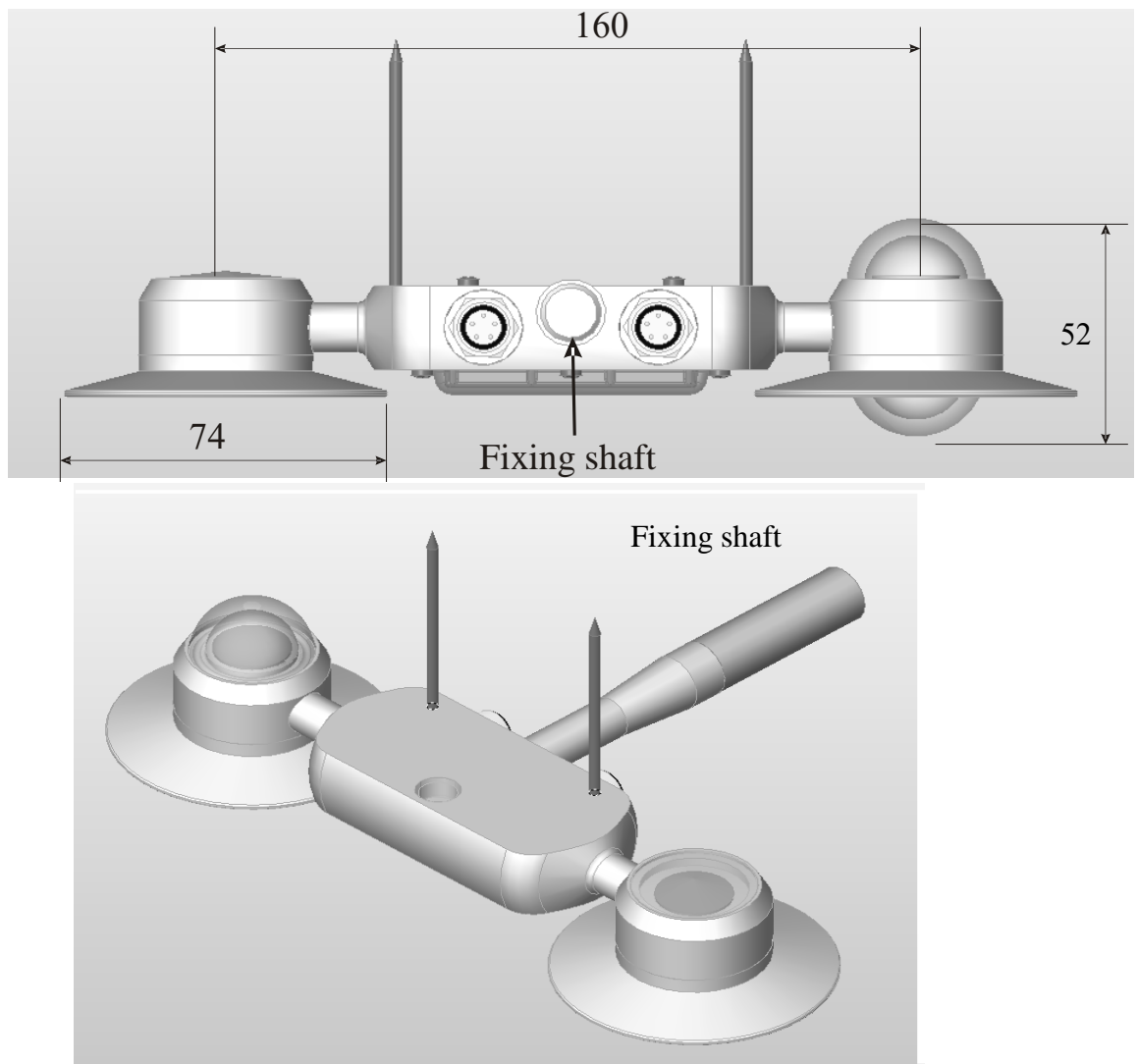


Fig. 4

4 Electrical Connections and requirements for electronic reading:

- The net-radiometer LPNET14 does not need any power supply.
- The instrument is equipped with two M12 8 pole connectors.
- The optional cables end with an 8 pole connector on one side and open wires at the other side. The cable is made in UV-resistant PTFE and is provided with 7 wires plus braid (screen), the diagram with the correspondence between wire colors and connector poles is the following (figure 5):

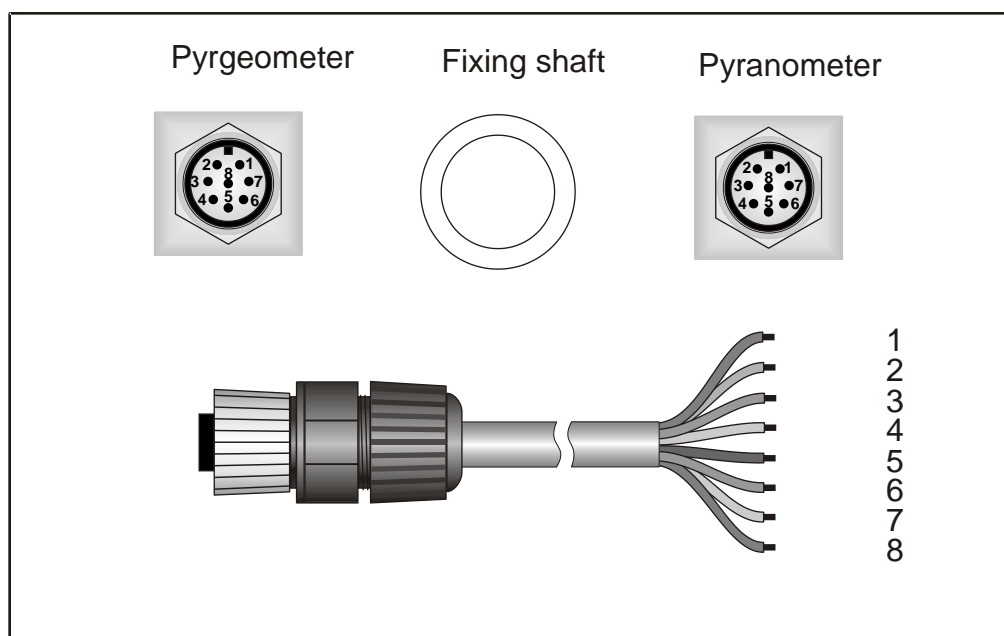


Fig. 5

Connector	Function		Colour
	Pyrgometer	Pyranometer	
1	$V_{out} (+) E_{FIR} \downarrow$	$V_{out} (+) E_{SW} \downarrow$	Red
2	$V_{in} (-) E_{FIR} \downarrow$	$V_{in} (-) E_{SW} \downarrow$	Blue
3	Screen	screen	Screen
4	NOT CONNECTED		
5	$V_{out} (-) E_{FIR} \uparrow$	$V_{out} (-) E_{SW} \uparrow$	Brown
8	$V_{in} (+) E_{FIR} \uparrow$	$V_{in} (+) E_{SW} \uparrow$	Green
6	NTC	NON CONNESSO	White
7	NTC	Schermo ($\frac{1}{\sigma}$)	Black

Table 1: correspondence pin-function

In order to obtain a measure, it is necessary to acquire simultaneously the signal of the four thermopiles and the NTC.

To measure the output signals of the four thermopiles, the four channels have to be connected to a millivolt meter or a data logger. In order to fully exploit the features of the net-radiometer, the recommended resolution of the reading instrument is $1\mu\text{V}$. Moreover, it is necessary to read the NTC resistance so to determine temperature of the two pyrgeometers.

Under figure 6 the electrical connections necessary to read the signal of the four thermopiles and the NTC are reported.

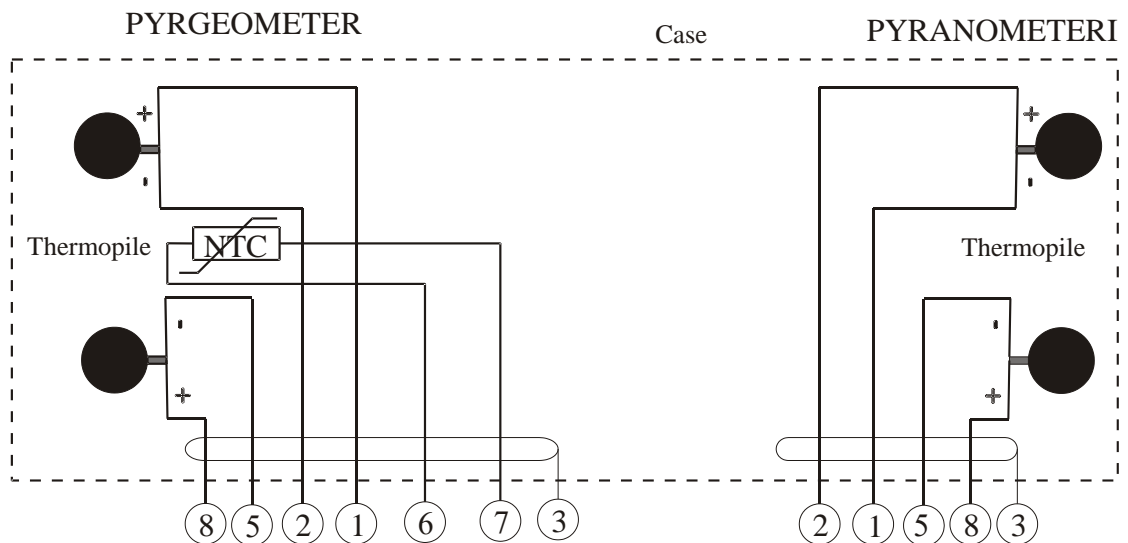


Fig. 6

5 Manutenzione:

In order to ensure a high measurement accuracy, it is necessary to always keep clean the silicon window and the glass domes of the net-radiometer, so the higher the frequency of cleaning is the best measurement accuracy will be. Cleaning can be done with normal maps for cleaning photographic objectives and water, if not possible, simply use pure ethyl alcohol. After cleaning with alcohol, it is necessary also to clean the window again in silicon with water only.

Due to the high temperature fluctuations between day and night, it is possible that you get some condensation inside the pyrgeometers and pyranometers (especially on the window in silicon); in this case the reading is done wrong. To minimize condensation inside the pyrgeometers, a proper cartridge with absorbent material is inside: Silica gel. The efficiency of silica-gel crystals decreases over time with the absorption of moisture. Typically, the duration of silica gel ranges from 4 to 12 months depending on environmental conditions the instrument operates in. In order to evaluate easily the efficiency status of the salt, within each charge there's a marker

added, to be placed at the bottom of the salt compartment so that it can be seen. When it indicates the presence of humidity, it is necessary to replace the salts. Hail of particular intensity or dimension may damage the silicon window, therefore, after an intense storm with hail, it is recommended to check the status of the window.

6 Calibration and measurements:

Each pyranometer and pyrgeometer that composes the instrument is calibrated individually. The calibration factor S is given in $\mu V/(Wm^{-2})$.

- Once the potential difference (DDP) has been measured at sensor ends E_e flux is obtained through the following formula

$$E_e = DDP/S$$

where;

E_e : indicates the radiant flux expressed in W/m^2 ,

DDP: indicates the potential difference expressed in μV and measured by the multimeter

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

Each net radiometer comes factory calibrated and has its own calibration factor.

The measurement with the two pyrgeometers has to be performed as follows:

According to the NTC R_{NTC} [ohm] resistance it is possible to trace the pyrgeometer temperature (T_b) back by using the formula 3:

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

Where:

$a=10297.2 \times 10^{-7}$;

$b=2390.6 \times 10^{-7}$;

$c=1.5677 \times 10^{-7}$.

Temperature is expressed in Kelvin degrees.

N.B. The values between $-25^\circ C$ to $+58^\circ C$ are tabulated in Table 2, to obtain the value in degrees Kelvin, use the appropriate conversion.

T [C]°	R_NTC [Ω]	T [C]°	R_NTC [Ω]	T [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

Table 2: NTC resistance values as a function of temperature.

Once the pyrgeometer temperature in Kelvin degrees (=Temperature in °C + 273.15) and the thermopile output signal U_{emf} [μV] are known U_{emf} [μV], $E_{FIR\downarrow}$ [W/m^2] irradiation is obtained by the formula 4:

$$E_{FIR\downarrow} = \frac{U_{emf}}{C} + \sigma T_B^4 \quad 4$$

Where:

C = pyrgeometer calibration factor [$\mu V / (W/m^2)$] reported on the calibration report;

σ = Stefan-Boltzmann constant ($5.6704 \times 10^{-8} W m^{-2} K^{-4}$).

Each pyrgeometer is individually calibrated at the factory and is distinguished by its calibration factor. Pyrgeometer calibration is performed outdoors, for comparison with a sample pyrgeometer calibrated by the World Radiation Centre (WRC).

The two instruments are kept outdoors for a few days and nights in the presence of clear sky. The data acquired by a data logger is then processed to obtain the calibration factor.

To fully exploit the features of the probe LPNET14, it is recommended to perform the calibration verification every one or two years (the choice of calibration interval depends both on the accuracy to be achieved and on the installation location).

7 Technical specifications

PYRANOMETERS

II° Class pyranometer according to ISO 9060

Typical sensitivity:	5 to 15 $\mu\text{V}/(\text{W}/\text{m}^2)$
Impedance:	33 Ω ÷ 45 Ω
Measuring range:	0-2000 W/m^2
Viewing field	2 π sr
Spectral range: (dome transmission)	305 nm ÷ 2800 nm (50%) 335 nm ÷ 2200 nm (95%)
Working temperature	-40 °C ÷ 80 °C

PYRGEOMETERS

Typical sensitivity:	5 to 15 $\mu\text{V}/(\text{W}/\text{m}^2)$
Impedance:	33 Ω ÷ 45 Ω
Measuring range:	-300+300 W/m^2
Viewing field:	160°
Spectral range: (silicon window transmission)	4.5 μm ÷ 45 μm (50%)
Working temperature	-40 °C ÷ 80 °C

8 Ordering Codes

ORDERING CODES

LPNET14

Net-radiometer equipped with: bracket Ø 16 mm length 400 mm, 2 bird spikes, 5 recharges of desiccant (composed of 2 silica-gel cartridges and one marker), level. 2 8-pole M12 flying connectors and Calibration Report.

ACCESSORIES

LPG2

5 recharges composed of 2 silica gel cartridges.

CPM12AA8.5

Cable with 8-pole M12 connector, 5 meters long.

CPM12AA8.10

Cable with 8-pole M12 connector, 10 meters long.