Graphic 1: 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:

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

Where:

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

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

σ = Stefan-Bolzmann constant (5.6704x10^{-8} W m^{-2} K^{-4});

T_B = pyrgeometer temperature (K), obtained by the reading of the NTC (10kΩ) resistance. In the manual (Table 1) is reported the resistance value according to the temperature for values included between -25°C and +55°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 (assuming emissivity ε=1) at T_B temperature.

LP PIRG 01
PYRGEOMETER

The pyrgeometer LP PIRG 01 is used to measure the far infrared radiation (FIR). Its use is mainly in the meteorological field. Measures are referred to radiations with wavelength greater than 4.5 μm .
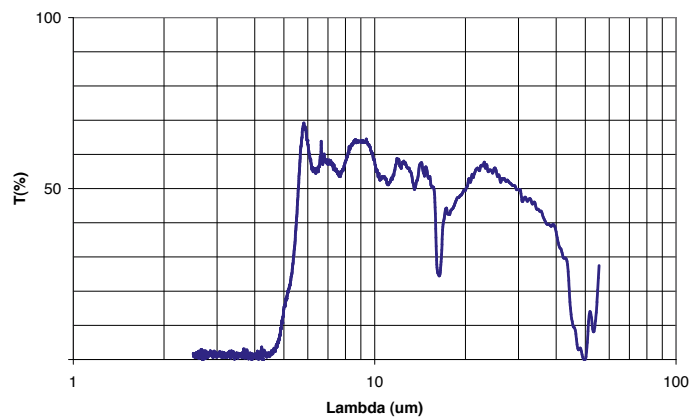
The far infrared radiation derives from the measure of the thermopile output signal and from the knowledge of the instrument temperature. The temperature measure is performed by a 10kΩ NTC which is inside the body of the pyrgeometer.

The pyrgeometer can be used also for the study of energy balance. In this case, besides another pyrgeometer which measures infrared radiation upwards, it is necessary an albedometer (LP PYRA 05 or LP PYRA 06) to measure short wavelengths radiation (<3μm) .

Working Principle

The pyrgeometer LP PIRG 01 is based on a thermopile sensor which surface is covered by a matt black paint so to allow the instrument not to be selective at various wavelengths. The sensor is covered by silicon window that has two basic purposes:

1- protect the thermopile from the weather;

2- determine the instrument spectral range: silicon is transparent to wavelengths longer than 1.1um 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 possibility of cleaning the surface without risk of scratching the window. Graphic 1 reports the transmission of the silicon window according to the wavelength variation:

3 Installation and mounting of the pyrgeometer for the infrared radiation measure:

Before installing the pyrgeometer you need to load the cartridge containing silica gel crystals. The silica gel has the function of absorbing humidity present inside the instrument; 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 three screws that fix the white screen

2- unscrew the Silica gel cartridge by using a coin

3- remove cartridge perforated cap

4- open the envelope (included with the pyrgeometer) containing the silica gel

5- fill the cartridge with silica-gel crystals

6- close the cartridge with his cap, making sure that the O-ring seal is positioned correctly

7- screw the cartridge into the body of the pyrgeometer with a coin

8- make sure that the cartridge is firmly screwed (if not the duration of the crystals of silica gel is reduced)

9- place the screen and screw it

10- the pyrgeometer is ready to be used

Figure 1 shows the operations necessary to fill the cartridge with the silica-gel crystals.
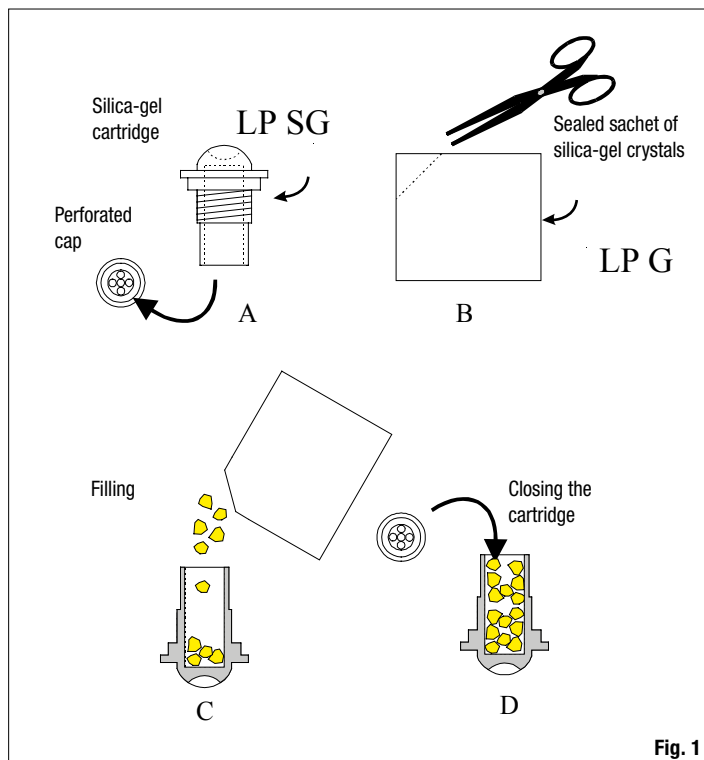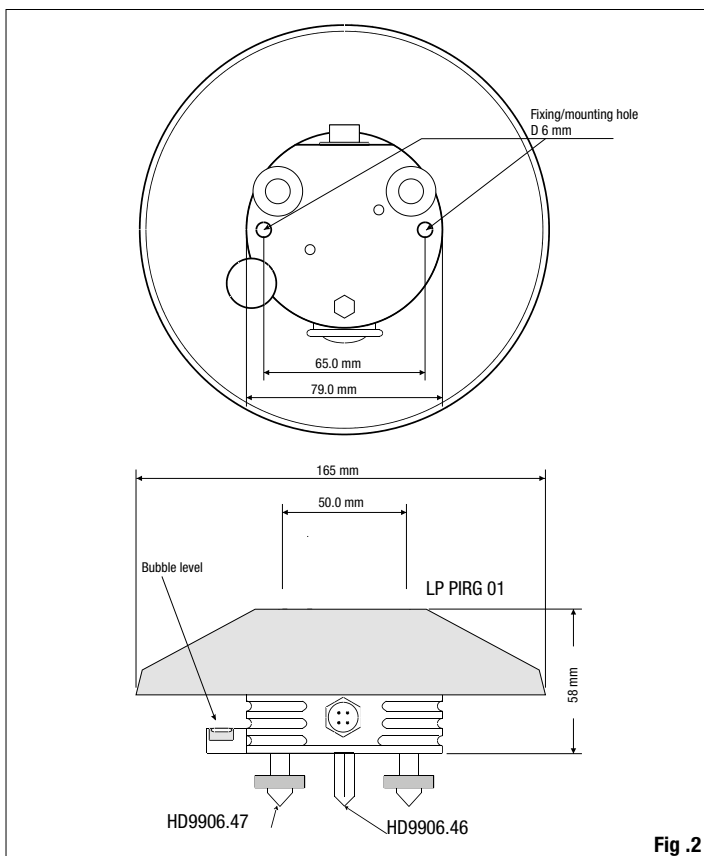
Environmental Analysis

Fig. 1

Fig .2

- The LP PIRG 01 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 the pyrgeometer lies. 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 WMO/ISO recommendations also when the screen is used.
- For an accurate horizontal positioning, the pyrgeometer LP PIRG 01 is equipped with a spirit level, which adjustment is by two screws with lock nut that allows changing the pyrgeometer inclination. The fixing on a flat base can be performed by using two 6mm diam. holes and 65 mm wheelbase. In order

to access the holes, remove the screen and re-place it back after mounting, see figure 2.
- The support LP S1 (figure 3), supplied upon request as an accessory, allows an easy mounting of the pyrgeometer support pole. The maximum diameter of the pole to which the bracket can be secured is 50 mm. To secure the pyrgeometer to the bracket, remove the screen by unscrewing the three screws, fix the pyrgeometer; once the installation is complete, fix the white screen back.
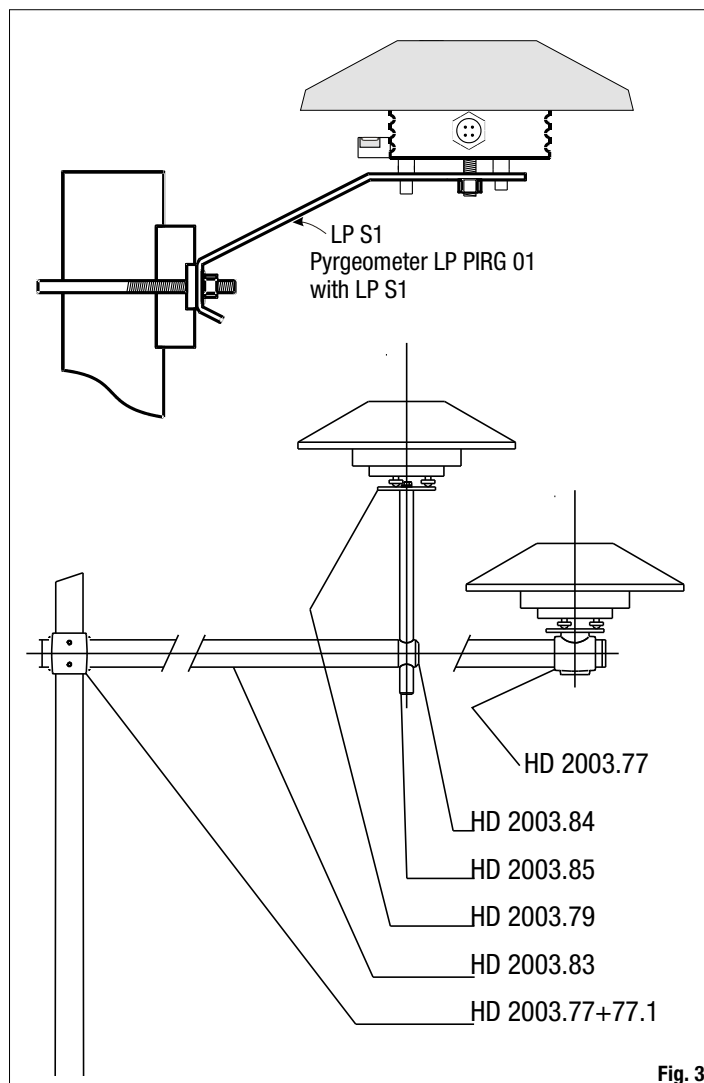

Fig. 3

4 Electrical Connections and requirements for electronic reading:
- The pyrgeometer LP PIRG 01 does not need any power supply.
- The instrument is equipped with an 8-poles M12 output
- The optional cable, ending with a connector by one side, is made in PTFE resistant to UV and is provided with 7 wires plus braid (screen), the diagram with the correspondence between cable colours and connector poles is the following (figure 4):
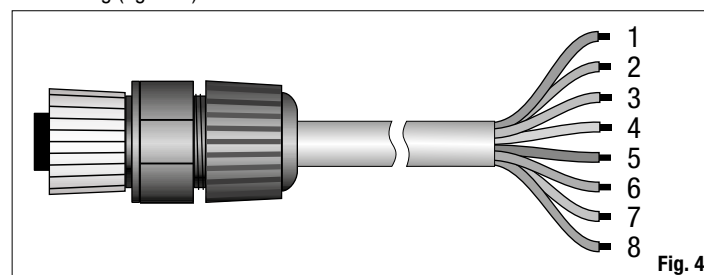
Fig. 4

Connector	Function	Colour
1	$V_{out}(+)$	Red
2	$V_{in}(-)$	Blue
3	Contenitore ($\perp$)	White
5	NTC	Brown
8		Green
7	Screen ($\perp$)	Black
6 and 4	NOT Connected	

Figure 4: correspondence pin-function

To measure the output signal from the thermopile (Chapters 1-2) the pyrgeometer has to be connected to a data-logger or digital voltmeter (DVM). Typically the output signal from the pyrgeometer is $|U_{emf}|<4$ mV. In order to fully exploit the features of the pyrgeometer, the recommended resolution of the reading instrument is 1 μV.

Moreover, it is necessary to read the NTC resistance so to determine the pyrgeometer temperature.

In Figure 5 the electrical connections present inside the pyrgeometer are reported.

Fig. 5
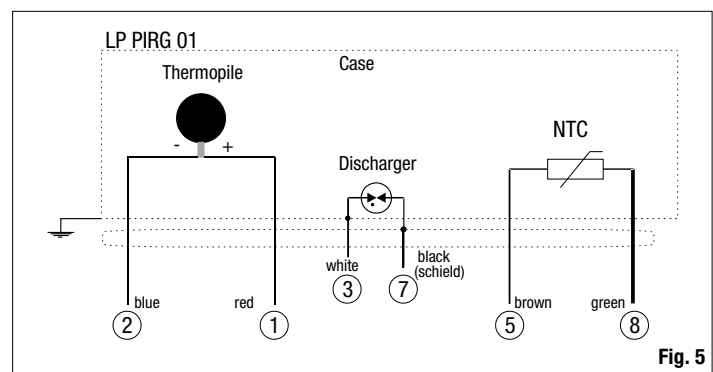
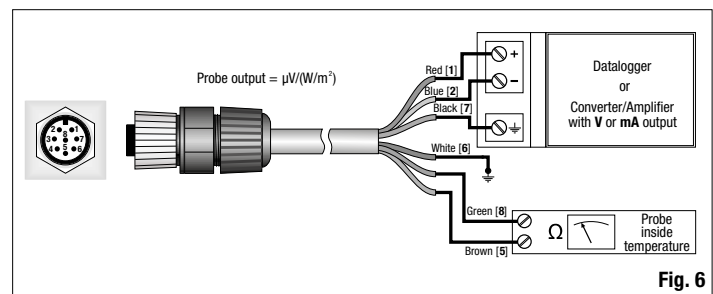Under figure 6 you can see a typical example of connection:

Fig. 6

Figure 6: example of connection of pyrgeometer

5 Maintenance:

In order to ensure a high measurement accuracy, it is necessary to keep clean the silicon window, so the higher the frequency of cleaning, 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 pyrgeometer (especially on the silicon window); in this case the reading is wrong. To minimize condensation inside the pyrgeometer, a proper cartridge Silica gel is supplied with the instrument.

The efficiency of silica-gel crystals decreases over time with the absorption of moisture. When crystals of silica gel are efficient their colour is yellow, while when gradually losing efficiency their colour becomes transparent; in order to replace them please refer to the instructions under paragraph 3. Silica gel typically lifetime goes from 4 to 12 months 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:

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

$$\frac{1}{T_b}=a+b\cdot\log(R_{NTC})+c\cdot\log(R_{NTC})^3 \qquad 3$$

Where:
a=10297.2x10^-7;
b=2390.6x10^-7;
c=1.5677x10^-7.
Temperatura is expressed in Kelvin degrees.

N.B. In table 1 you can get the vakues between -25°C and +58°C; in order to obtain the value under Kelvin degrees it is necessary to sum 273.15 to the value read in Celsius degrees.

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 1: values of NTC resistence according to the temperature.

Once the pyrgeometer temperature in Kelvin degrees and the thermopile output signal are known U_{emf} [μV], irradiation $E_{FIR}\downarrow$ [W/m²] is obtained by the formula 1:

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

Where:

C = pyrgeometer calibration factor [μV /(W/m²)] reported on the calibration report;

σ = Stefan-Bolzmann constant (5.6704x10^-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 reference standard pyrgeometer calibrated by the Word Radiation Center (WRC).

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

To take full advantage of the LP PIRG 01 features, we recommend to perform the calibration every one, two years (the choice of calibration interval depends both on the accuracy to be achieved and on the installation location).

7 Technical specifications:

Typical sensitivity:	5-10 μV/(W/m²)
Impedance:	33 Ω ÷ 45 Ω
Measuring range:	-300;+300 W/m²
Field of view:	160°
Spectral range:	5.5 μm ÷ 45 μm (50%)
(transmission from the silica window)	
Working temperature:	-40 °C ÷ 80 °C
Dimensions:	figure 2
Weight:	0.90 Kg

Technical specifications according to ISO 9060

Response Time:	<28 sec
(95%)	
Off-set Zero (type B):	response to a change of 5K/h
of room temperature:	$<|\pm4|$ W/m²
Long-term instability:	$<|\pm1.5|$ %
(1 year)	

Nonlinearity:	< │ ±1 │ %
Spectral selectivity:	< │ ±5 │ %
Temperature response:	<3 %
Tilt response:	< │ ±2 │ %

PURCHASING CODES

LP PIRG 01: Pyrgeometer. Equipped with protection, silica-gel crystals cartridge, 2 richarges, level. 8-poles M12 connector and Report of Calibration ISO9001.

LP S1: Kit made of bracket for mounting pyrgeometer LP PIRG 01 to a pole with diameter 50mm

LP SP1: Protection screen made in plastic UV resistant. LURAN S777K della BASF

LP SG: Cartridge for silica-gel crystals equipped with OR and cap

HD2003.77: Compass for positioning the pyrgeometer on a 40mm diameter tube

HD2003.85K: Kit for fixing the pyrgeometer on a 40mm diam pole, with adjustable height (HD2003.84 – HD2003.85 – HD2003.79)

LP G: Pack of 5 cartridges of silica gel crystals