

**Notice**

*Please read this manual before using the net radiometer.  
The manufacturer shall not be liable for incidental or  
consequential damage in connection with the furnishing,  
performance or use of this manual and the sensor that is  
described in this manual.*

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## 1. General information

The net radiometer NR *LITE* is an instrument for measuring solar and far infra red radiation balance. This balance is usually called net (total) radiation. Its up facing sensor measures the solar energy and far infra red energy that is received from the entire hemisphere (180 degrees field of view). Its down facing sensor measures the energy received from the soil surface. The down facing sensor reading is automatically subtracted from the up facing sensor value and converted to one output signal. The resulting output represents the net radiation, which can be interpreted as the radiative energy that is absorbed by the soil surface. The output is expressed in Watts per square metre.

The net radiometer is designed for continuous outdoor use. Contrary to most common instruments for measurement of net radiation, it is not equipped with plastic domes. The domes are replaced by a teflon coated sensor surface. This has big advantages for maintenance and sensor stability, it also has disadvantages; most particularly a higher sensitivity to wind speed (see 2.4). Therefore the accuracy of the instrument is limited.

In its most frequent application the net radiometer is used for measuring the radiation balance as a meteorological parameter. It can however also be used to measure indoor climate radiative stress.

Contrary to similar designs of other brands, the net radiometer is not equipped with a level. The reason is that for the kind of accuracy that this sensor can offer, leveling does not need to be accurate, and your own visual observation is sufficient to act as a guideline.

The NR *LITE* fully complies with  directive 89/336/EEC

## 1.1 Five minutes user guide

### *Requirements:*

1. net-radiometer
2. voltmeter with a range from 0 to 50 millivolt and an input impedance of more than  $5000\Omega$
3. light
4. your own hand
5. a table

Position the instrument such that the down facing sensor is 1 centimeter over a surface (e.g. a table), and the upper sensor is facing the lamp. Please avoid contact between the sensor and your hand; this creates thermal shocks to which the sensor is sensitive. Hold the sensor at the rod at all times.

- Connect the net radiometer wires to the voltmeter, the white wire to the voltmeter +, the green wire to the voltmeter -.
- Put the voltmeter range to the most sensitive.
- With the lamp off, read the sensor signal (it takes about a minute for the signal to stabilize).
- Expose the sensor to light. The signal should give a more positive reading.

- Put the lamp off again, the signal should slowly return to the old signal level. This shows that the sensor is sensitive to light.
- Put the sensor upside down. The signal should reverse sign (+10 mV should become -10 mV), because it measures upper minus lower sensor. Don't worry about a 20% difference under these conditions! If OK, put the sensor in its original position again, and let it stabilize.
- Put your hand over the upper sensor. The signal should give a more positive reading, provided that the sensor temperature is lower than the temperature of your hand. If the temperature of your hand is lower than the temperature of the sensor, the signal will go more negative.
- The sensitivity to thermal shocks can be demonstrated by touching the sensor edge (the blank metal) with your hand for some seconds. The resulting shock will result in a signal drift, or a zero offset that only slowly will settle down again.

- Adjust the voltmeter range in such a way that the expected full scale output of the net radiometer fits the full scale input of the voltmeter. This can be done on theoretical considerations. (When the maximum expected radiation is +1500 Watts per square metre, the minimum is -200, and the sensitivity of the net radiometer is 10 microvolts per Watt per square metre, the expected output range of the pyranometer is 1700 times 10 makes 170.00 microvolts or 0.017 volts.) These values are applicable for normal meteorological applications.
- Calculate the radiation intensity by dividing the net radiometer output (0.017 volts) by the calibration factor (0.000010 volt per watt per square metre).
- For permanent installation mounting should be done using the net radiometer mounting rod. The sensor should be mounted in a field which is free from obstructions. Under no condition a shadow should be cast upon it.
- Maintenance: the sensor should be kept clean, using water or alcohol. Please treat the surface gently.
- Recalibration is suggested every two years, preferably by letting a higher standard run parallel to it during two sunny days, and by comparing the daily totals. This reference could be a net radiometer type CNR1, or a NR *LITE* that is kept safely in the cupboard (sensor stability mainly is a matter of aging of the sensor surface black paint) . Another

way of checking sensor performance during field use, is to put the sensor upside down during stable atmospheric conditions. Theoretically the sensor output should change sign. This method is no more accurate than 20% because of the fact that the sensor symmetry is no more accurate than this.

## 2. Sensor properties

The net radiometer consists of a thermopile detector, two black teflon coated sensor surfaces, a housing and a cable. The thermopile consists of a number of thermocouples that are connected in series. It essentially is a very sensitive differential temperature sensor. The thermopile generates a voltage output (the sensor is passive, no power supply required). The up facing sensor surface is connected to the upper joints of the thermopile, the down facing sensor is connected to the lower joints of the thermopile. The sensor will measure the temperature difference between the upper and the lower sensor surface. This temperature difference can very accurately be determined (changes of less than 0.001 degree are detectable. The temperature difference is proportional to the net radiation.

Most electrical specifications are determined by thermopile. Spectral specifications are determined by the black teflon coating.

Both the up facing and the down facing sensors have a field of view of 180 degrees, and their angular characteristics fulfill the so-called cosine response.

## 2.1 Electrical

The electrical circuit of the net radiometer is drawn in figure 1. The nominal output resistance of the net radiometer is  $2.3 \Omega$ . This implies that the input impedance of the readout equipment should at least be  $2300 \Omega$  in order to make an error of less than 0.1 percent.

Cable can be extended without problems to a length of 100 metres, provided that cable resistance is less than 0.1 percent of the input impedance of the readout equipment.

The electrical sensitivity of the thermopile changes with the temperature. A nominal value for this is not specified.

Calibration is done at 20 degrees Celsius.

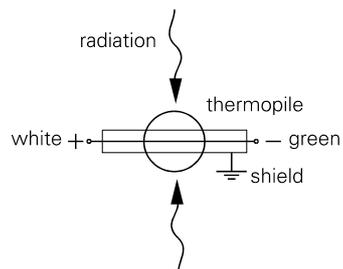
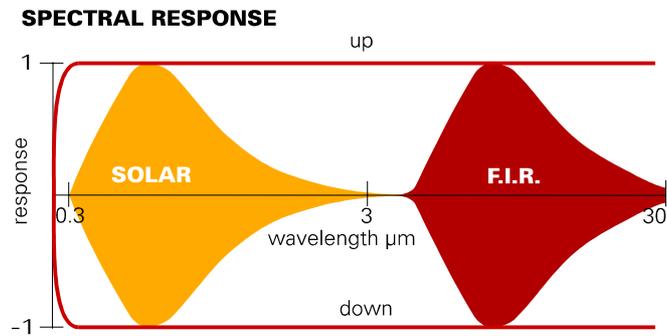


Figure 1 *Electrical circuit of the net radiometer.*

## 2.2 Spectral

The spectral properties of the net radiometer are determined by the teflon sensor surface. The spectral sensitivity is not specified in our list of specifications because it is not considered to be of critical importance. A sketch of approximate spectral sensitivity is given in figure 2.



*Figure 2* The approximate spectral sensitivity of the net radiometer combined with the spectrum of the sun under a clear sky, and the spectrum of outgoing far infra red radiation.

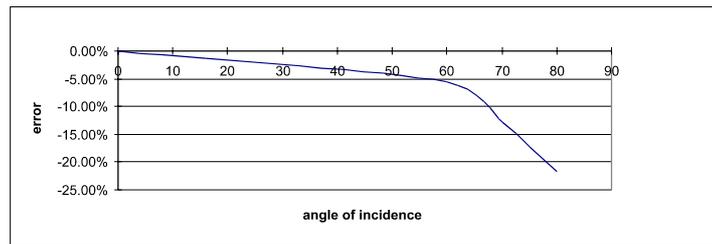
The up facing sensor has been calibrated for solar radiation wavelengths. It is assumed that the lower sensor has the same sensitivity. This might not be true; the sensor can have a non perfect symmetry. This however is neglected. Secondly it is assumed that the sensor sensitivity to infra red radiation is the same as for solar radiation.

### 2.3 Directional/Cosine response

The measurement of the radiation falling on a surface (also called irradiance or radiative flux) requires two assumptions: that the surface is spectrally black (that it absorbs all radiation from all wavelengths, see previous paragraph) and that it has a field of view of 180 degrees. Another way of expressing these directional properties is to say that the sensor has to comply with the cosine response.

The net radiometer sensor surface has a rather special shape, it is shaped like a cone, in order to have a better compliance with the cosine response.

A perfect cosine response will show maximum sensitivity (1) at an angle of incidence of 0 degrees (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90 degrees (radiation passing over the sensor surface). In between 0 and 90 degrees the sensitivity should be proportional to the cosine of the angle of incidence. Figure 3 shows the behavior of a typical net radiometer. The vertical axis shows the deviation from ideal behavior, expressed in percentage deviation of the ideal value.



*Figure 3* The directional response or cosine response of the net radiometer. On the horizontal axis the zenith angle (0 degrees zenith angle equals 90 degrees angle of incidence). On the vertical axis the percentage deviation from ideal cosine behavior. The specifications of the net radiometer regarding the cosine response are very good because the detector surface is shaped like a cone.

## 2.4 Sensitivity to wind speed

The net radiometer is calibrated at zero wind speed. At higher wind speeds, the sensitivity and thus voltage output will decrease. Applying the original sensitivity figure result in too low net irradiances. The design however was made such that this error generally will not be large, so that correction is not necessary. This is achieved by keeping the sensor- $\Delta T$  low.

For scientific research to this matter a correction theoretically could be done by multiplying the calculated irradiances with a factor  $(1+x.v^{3/4})$  where  $v$  is the wind speed in m/s, and  $x$  has to be determined empirically.  $x$  is found to be approx. 0.01.

## 2.5 List of specifications

### Electrical

- Impedance (nominal) 2.3  $\Omega$
- Response time (1/e): < 20 SEC
- Sensitivity (nominal): 10  $\mu V/W/m^2$
- Expected signal range under atmospheric conditions: -25 to +25 mV
- Stability: <  $\pm 2\%$  per year
- Non linearity (estimated): < 1 % up to 2000  $W/m^2$
- Temp. dep. of sensitivity: not specified

### *Spectral*

- Spectral range: 0.2-100  $\mu\text{m}$
- Detector type: Thermopile
- Detector protection: Teflon coating
- Detector shape: Cone

*Directional*

- Directional error 0-60°  
at 1000  $\text{W}/\text{m}^2$  < 30  $\text{W}/\text{m}^2$
- Sensor asymmetry:  $\pm 20\%$

*Mechanical*

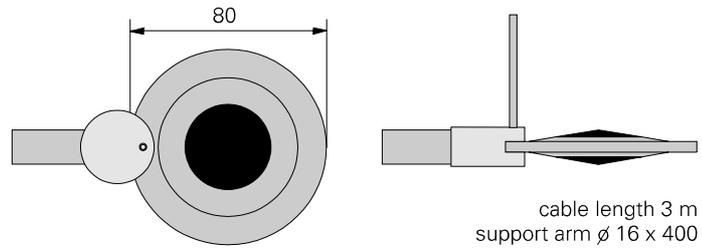
- Material of housing: Anodised aluminium
- Material of cable: Poly Urethane
- Weight: 200 g
- Cable length: metres
- Dimensions see figure 4

*Environmental*

- Working temperature range: -30 - +70  $^{\circ}\text{C}$

*Calibration conditions*

- The upper sensor is calibrated for solar radiation
- traceable to Kipp & Zonen secondary standard pyranometer.
- normal incidence, 500 Watt per metre square, 20 degrees Celsius, horizontal position, zero wind speed.

**2.6 Dimensions**

*Figure 4 The dimensions of the net radiometer in mm, white lead positive, green lead negative.*

### 3. Calibration

The up facing sensor of the net radiometer is the one that is calibrated for solar radiation. It is silently assumed that the sensitivity of the downfacing sensor is the same. In reality this might differ. (see specifications). This error is accepted because the down facing sensor signal will generally be at least a factor 3 smaller than the signal of the up facing sensor. Also it is assumed the sensitivity to infra red radiation is the same as for solar radiation. The error caused by this is unknown. It is neglected because the solar radiation will be the dominating factor. Another error is caused by wind this error is specifically treated in chapter 2.4. During calibration there is no wind. It is suggested not to correct for this; to improve the accuracy of this instrument would require more than a wind correction. The up-facing sensor of the NR *LITE* net radiometer reference is calibrated against a Kipp & Zonen secondary standard pyranometer (this is a radiometer that is sensitive to solar radiation only) under natural sunlight during clear sky conditions. Further reference conditions are as follows: temperature 20 degrees Celsius, irradiance 500 Watts per square metre, wind speed < 2 m/s. The primary standard for solar radiation, against which the secondary standard pyranometer is calibrated, is the World Radiometric Reference.



#### 4. Installation and maintenance

When installed permanently, the net radiometer can be attached to a mast using the rod that is attached to the sensor. The rod diameter is standardized to Kipp & Zonen diameter. Leveling can be based on your own visual observation. When installed on a mast, preferred orientation is such that no shadow is cast on the net radiometer during any time of the day. On the northern hemisphere this implies that the net radiometer should be south of the mast.

It is advised to measure at a height  $h$  of at least 1.5 meters above the surface in order to avoid shading effects and to promote spatial averaging.

The down facing sensor signal is representative (99%) for a circular area with radius  $10 h$ .

The net radiometer is an all weather instrument.

Once installed it needs little maintenance. It is suggested to clean the detector as part of a regular routine, using water or alcohol.

Recalibration is suggested every two years, preferably by letting a higher standard run parallel to it during two sunny days, and by comparing the daily totals. Preferably daily totals of several days should be compared. Calibration factor could be corrected if results differ by more than five percent. The reference could be a net radiometer type CNR1, or a NR *LITE* that is kept safely in the cupboard. Another way of checking sensor performance during field use, is to put the sensor

upside down during stable atmospheric conditions. Theoretically the sensor output should change sign. Please mind that the sensor response time for stabilizing is about one minute. This method is no more accurate than 20% because of the fact that the sensor symmetry is no more accurate than this.

A third way is to let a recalibration be performed at Kipp & Zonen B.V.

## 5. Trouble shooting

*If your net radiometer does not seem to work at all, please follow the following procedure:*

- Check if the net radiometer reacts to light, using the procedure in the "five minutes user manual".
- No result? Measure the impedance of the sensor across the white and the brown wires. This should be close to 2.3 ohms. If it is close to five ohms, there is a short circuit. If it is infinite, the thermopile is blown.

*If the net radiometer shows bigger or smaller results than expected, the following questions might help you out:*

- Are you measuring under natural sunlight? If so the maximum expected radiation is 1500 Watts per square metre. Under lamps this might be more. For indoor climate studies, smaller values are expected unless solar radiation is present. A typical value for a room when facing a wall and a relatively cold window is 50 Watts per square metre.
- Are you correcting for the calibration factor? Please note that this factor is an individual property, that is different for each sensor. Do you divide by the factor? This is correct.
- What is the input impedance of your readout equipment? It should preferably be more than 5000 ohm. If smaller than 250 ohm you will notice errors.

- Is your readout equipment properly calibrated?

*If still no satisfactory answer is found, please contact your supplier.*

## 6. Delivery

Delivery includes:

- 1 net radiometer
- 1 bird stick (to be installed on the net radiometer)
- 1 calibration certificate
- 1 manual



## 7. Accessories

No options or accessories are available.