

**CNR 1**  
Net radiometer

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# Instruction Manual



## IMPORTANT USER INFORMATION

**Reading this entire manual is recommended for full understanding of the use of this product.**

The exclamation mark within an equilateral triangle is intended to alert the user to the presence of important operating and maintenance instructions in the literature accompanying the instrument.

Should you have any comments on this manual we will be pleased to receive them at:

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## DECLARATION OF CONFORMITY

**According to EC guideline 89/336/EEC 73/23/EEC**

We: **Kipp & Zonen B.V.**  
**Delftechpark 36**  
**2628 XH Delft**  
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Declare under our sole responsibility that the product

Type: **CNR 1**  
Name: **Net-Radiometer**

To which this declaration relates is in conformity with the following standards

Imissions EN 50082-1 Group standard

Emissions EN 50081-1 Group standard  
EN 55022

Safety standard IEC 1010-1

Following the provisions of the directive



**B.A.H. Dieterink**  
President  
KIPP & ZONEN B.V.

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## 1 GENERAL INFORMATION

The Net Radiometer, CNR 1, is intended for the analysis of the radiation balance of Solar and Far Infrared radiation. The most common application is the measurement of Net (total) Radiation at the earth's surface.

Three of CNR 1 features are unique: first, it measures four radiation components separately, secondly, it is robust and virtually maintenance free, and thirdly, calibration of CNR 1 is relatively straightforward. These factors make the CNR 1 extremely suitable for long-term outdoor measurements. Especially in rough environments. Generally speaking, the CNR 1 will measure with a higher degree of accuracy than other competitive instruments. This is mainly because the dominant measurement of solar radiation with the CM 3 is accurate. Accuracy is also influenced positively by the possibility of viewing the four separate components of the radiation. In this way errors in the measurement can be detected more easily. Also contributing to a high degree of accuracy, is the CNR 1's high reliability, and, under conditions where other instruments would be covered by dew or frost, its incorporated heating.

The CNR 1 design is such that both the upward facing and the downward-facing instruments measure the energy that is received from the whole hemisphere (180 degrees field of view). The output is expressed in Watts per square meter. The total spectral range that is measured is roughly from 0.3 to 42 micrometers. This spectral range covers both the Solar Radiation, 0.3 to 3 micrometers, and the Far Infrared radiation, 4.5 to 42 micrometers.

The design of CNR 1 is such that Solar radiation and Far Infrared radiation are measured separately. This is a unique feature.

Solar radiation is measured by two pyranometers, one for measuring incoming radiation from the sky, and the other, which faces downward, for measuring the reflected Solar radiation. From these two pyranometers, albedo, the ratio of reflected and incoming radiation, can also be determined. The model type indication for the pyranometers is CM 3.

Far Infrared radiation is measured by two pyrgeometers, one for measuring the Far Infrared radiation from the sky, the other from the soil surface. The model type indication of the pyrgeometer is CG 3. The CNR 1 can be used in two ways: measuring the four components separately, the four Separate Components Mode (4SCM) or measuring only Net Radiation, the Net Radiation Mode (NRM).

Chapter 1 describes how to operate the CNR 1, giving separate attention to the 4SCM, the NRM and the use of the individual sensors CM 3 and CG 3.

More about the physics of the CM 3 and CG 3 can be found in chapter 2.

**Warning:** The CNR 1 contains shunting resistors in its body. Their function is to trim the sensitivities of each one of the CNR 1's four individual sensors, to the same sensitivity. The output calibration constant thus is the same for all four sensors. This constant is indicated on the side of the CNR 1's body.

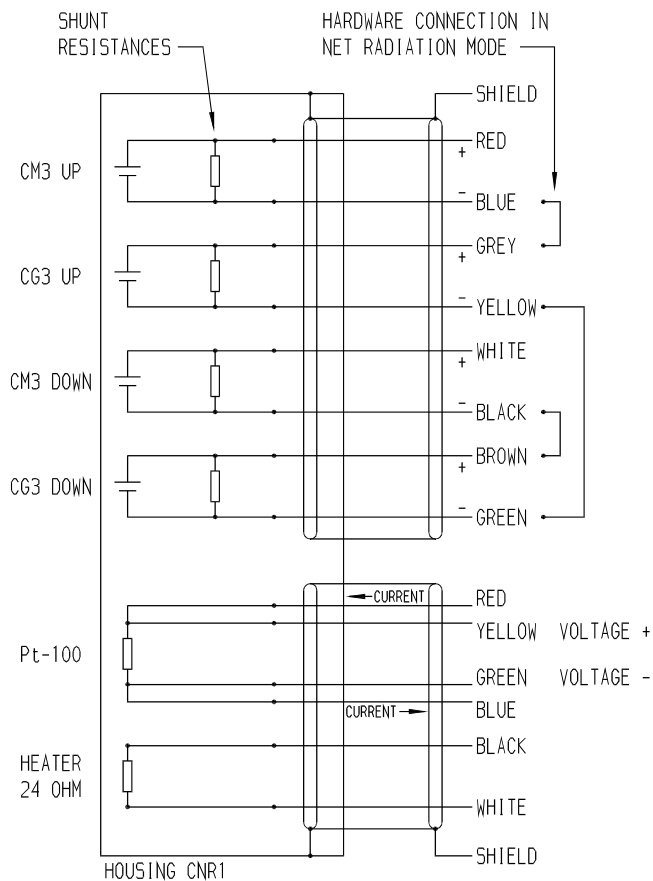
For quality assurance of the measurement data, we recommend the recalibration of the CNR 1 as part of a regular maintenance schedule. More about calibration can be found in chapter 3.

The CNR 1 is intended for continuous outdoor use. It is weatherproof. The materials used in CM 3 and CG 3 are robust. Contrary to most competitive instruments, plastic domes are not used. Therefore the CNR 1 requires very low maintenance. For optimal results however, proper care must be taken. More about maintenance can be found in chapter 4. Chapter 5 can be consulted if a problem with the CNR 1 is suspected; this chapter addresses trouble shooting. The general user should read chapter 1 and chapter 4.

## 1.1 USING THE CNR 1

### 1.1.1 The minimum necessary requirements before working with the CNR 1

CNR 1 has several output signals: two voltages for the model type CM 3 pyranometers, two voltages for the model type CG 3 pyrgeometers, and a 4 wire Pt-100 connection. A heater is incorporated. The heater is intended to prevent dew and frost deposition at night. Heating generally improves accuracy but at the same time introduces some measurement errors. It is not a necessity. An electrical diagram of CNR 1 is depicted in figure 1.1.



COMMENT:

1. When Pt-100 is replaced by a thermistor, the current wires are disconnected.
2. The heater is not necessarily used.

Figure 1.1 The electrical diagram of the CNR 1. The sensor has four mV outputs, one (4-wire) Pt-100 output and a heater with a 2-wire connection.

When used in the **NRM** configuration, (**measuring Net Radiation only**), the four mV outputs should be connected as indicated by the line on the right side of the drawing, creating one single output. In this case the lower sensors are electrically connected in anti-series with the upper sensors because the signals of these sensors must be subtracted from the signals of the upper sensors. In the NRM configuration, the Pt-100 signal is not essential. All connections should be soldered. In the **4SCM** configuration, (**measuring two Solar Radiation signals, two Far Infrared signals and, for calculation purposes one Pt-100 signal**) all signals are measured separately, and the calculation of Net-Radiation and albedo are ultimately performed by the instrument user's own processing software. The sensitivities of the individual sensors are adjusted to the same sensitivity, using the trimming resistors. The resulting sensitivity is indicated on the side of the CNR 1's casing. The heater should only be used if a power supply is not a problem, to eliminate dew and frost deposition. It is not a necessity, and will introduce some measurement errors. Under most conditions the accuracy that is gained by heating will be larger than the errors that are introduced by heating. It runs on 12 VDC, 6 VA for dew prevention. Generally, it is suggested to heat only at night.

The CM 3's and the CG 3's have a voltage output in the mV range. The sensitivity of all these radiation sensors is trimmed to one single sensitivity. This is done inside the body of the CNR 1, using trimming resistors. The Pt-100 is a passive sensor: it requires a current input through 2 wires (typically 1 mA), and will yield a voltage output across the remaining two wires.

The CM 3 pyranometer generates a mV signal that is simply proportional to the incoming solar Radiation. The conversion factor between voltage, V, and Watts per square metre of solar irradiance E, is the so-called calibration constant C (or sensitivity).

$$\text{For the CM 3} \quad E = V/C \quad (1.1)$$

When using the CG 3 pyrgeometer, one should realise that the signal that is generated by the CG 3 represents the exchange of Far Infrared (thermal) radiation between the CG 3 and the object that it is facing. This implies that the CG 3 will generate a positive voltage output, V, when it faces an object that is hotter than its own sensor housing, and that it will give a negative voltage signal when it faces an object that is colder. This means that for estimating the Far Infrared radiation that is generated by the object that is faced by the pyrgeometer, usually the sky or the soil, one will have to take the pyrgeometer temperature, T, into account. This is why a Pt-100 is incorporated in the CNR 1's body. (This body is in very good thermal contact with the CG 3, and has the same temperature as the CG 3 sensor surface). The calculation of the Far Infrared irradiance, E, is done according to the following equation:

$$\text{For the CG 3 only} \quad E = V/C + 5.67 \cdot 10^{-8} \cdot T^4 \quad (1.2)$$

In this equation C is the sensitivity of the sensor. Please bear in mind that T is in Kelvin, and not in Celsius or Fahrenheit.

**Warning:** do not disconnect the sensors from their mounting: the trimming resistors inside the CNR 1's body must be kept with the radiometers at all times. CG 3 is that it will probably give voltage signals that are close to zero, assuming that the instrument temperature is close to the temperature of the earth's surface.

The CNR 1 can be used in two modes, the Net Radiation Mode, NRM, and the four Separate Components Mode, 4 SCM. In the NRM all the radiation signals are combined to form one signal only, representing the Net Radiation. In this case it is not necessary to measure the CNR 1's temperature because the term  $5.67 \cdot 10^{-8} \cdot T^4$  of equation 1.2 cancels from the equation when the difference between the two CG 3 pyrgeometer signals is calculated. In the 4SCM the separate components of Solar- and Far Infrared radiation are measured. In this case it is also necessary to measure the CNR 1's temperature using the Pt-100, for calculating the Far Infrared E according to equation 1.2.



When working with the CNR 1 in the NRM, the minimum requirement is one voltmeter, given a mV-input range. With this the Net-Radiation can be measured. Alternatively one can measure all the components separately, in the 4SPM. In this case one needs four mV channels, and one Pt-100 channel. The mV signal range is roughly 0 to 50 mV.

If possible, but not as a necessity, one should heat. For heating, a 12 VDC, 6 VA power supply, can be used.

### **1.1.2 Using the CNR 1 in the Four Separate Components Mode (4SCM)**

In the 4SCM all components are measured separately. This implies that one should connect the individual radiometers and the Pt-100. The two CM 3's will measure the solar radiation, both incoming and reflected, the two CG 3's will measure the Far Infrared radiation. For proper analysis of the CG 3 measurement results, they must be temperature corrected using the temperature measurement performed by the Pt-100. The following paragraphs describe how one should treat the instrument, and how different parameters like net Solar radiation, net Far Infrared radiation, soil temperature, sky temperature, and Net (total) radiation can be calculated.

#### **1.1.2.1 Measuring Solar radiation with the CM 3**

Measuring with a CM 3 can be done by connecting two CM 3 wires, + and -, to a voltmeter. Incidental light results in a positive signal. The pyranometer mounting plate and ambient air should be at the same temperature, as much as possible. Conversion of the voltage to irradiance can be done according to equation 1.1. This is sometimes done in the data logging system itself, sometimes during evaluation in the user's software. Measuring with the upward-facing CM 3, the so-called global (solar) radiation is measured. The downward-facing CM 3 measures the reflected solar radiation. When calculating the Net radiation, the Reflected radiation must be subtracted from the global radiation. See 1.1.2.5.

#### **1.1.2.2 Measuring Far Infrared radiation with the CG 3**

A measurement with the CG 3 can be performed by connecting two CG 3 wires, + and -, to a voltmeter. A signal radiating from a source which is warmer than the CG 3 results in a positive signal.

In the 4SCM, which we are now discussing, the purpose is to measure the Far Infrared irradiances with the two pyrgeometers, separately. For this measurement, the Pt-100 output is required. The formula 1.2 is used to calculate the Far Infrared irradiance of the sky and of the ground.

With the downward-facing CG 3, one would generally measure the Far Infrared radiation that is emitted by the ground. In contrast, the upward-facing CG 3 is generally used to measure the Far Infrared radiation from the sky. As the sky is typically colder than the instrument, one can expect negative voltage signals from the upward-facing CG 3. All one can say about the downward facing.

#### **1.1.2.3 Measuring the CNR 1's temperature with the Pt-100, or the optional thermistor.**

**Notice:** whenever the heater is used, the heating may cause errors in the measurement of the sensor temperature (two degrees typical) and zero offsets in the CM 3 (10 Watts per square metre typical).

To obtain a signal from the Pt-100, a current of about one mA is fed through two wires on either side of the PT-100. The voltage that is generated must be measured using the other pair of wires which are connected in parallel with the PT-100, see figure 1.1

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This is known as a 4-wire measurement. Measuring in this manner eliminates errors during measurement, which would be produced by additional wire length. Some systems have a 3-wire connection. In this case omit one current lead and follow the instructions of your measurement system manual. Table 1.1 states the Pt-100 resistance values as a function of temperature. Please note that for use in formula 1.2, one must use Kelvin, not degrees Celsius or Fahrenheit. Most data acquisition systems have standard readout and conversion for Pt-100's. As an option one can replace the Pt-100 with a 10k Ohm thermistor. The thermistor resistance values as a function of temperature are indicated in table 1.2.

Temperature [EC]	Resistance [ $\Omega$ ]	Temperature [EC]	Resistance [ $\Omega$ ]	Temperature [EC]	Resistance [ $\Omega$ ]
-30	88.22	0	100.00	30	111.67
-29	88.62	1	100.39	31	112.06
-28	89.01	2	100.78	32	112.45
-27	89.40	3	101.17	33	112.83
-26	89.80	4	101.56	34	113.22
-25	90.19	5	101.95	35	113.61
-24	90.59	6	102.34	36	113.99
-23	90.98	7	102.73	37	114.38
-22	91.37	8	103.12	38	114.77
-21	91.77	9	103.51	39	115.15
-20	92.16	10	103.90	40	115.54
-19	92.55	11	104.29	41	115.93
-18	92.95	12	104.68	42	116.31
-17	93.34	13	105.07	43	116.70
-16	93.73	14	105.46	44	117.08
-15	94.12	15	105.85	45	117.47
-14	94.52	16	106.24	46	117.85
-13	94.91	17	106.63	47	118.24
-12	95.30	18	107.02	48	118.62
-11	95.69	19	107.40	49	119.01
-10	96.09	20	107.79	50	119.40
-9	96.48	21	108.18	51	119.78
-8	96.87	22	108.57	52	120.16
-7	97.26	23	108.96	53	120.55
-6	97.65	24	109.35	54	120.93
-5	98.04	25	109.73	55	121.32
-4	98.44	26	110.12	56	121.70
-3	98.83	27	110.51	57	122.09
-2	99.22	28	110.90	58	122.47
-1	99.61	29	111.28	59	122.86

Table 1.1 Resistance values versus temperature of the CNR 1's Pt-100. The Pt-100 complies with the class A specifications of DIN.

Temperature [EC]	Resistance [Ω]	Temperature [EC]	Resistance [Ω]	Temperature [EC]	Resistance [Ω]
-30	135200	0	29490	30	8194
-29	127900	1	28150	31	7880
-28	121100	2	26890	32	7579
-27	114600	3	25690	33	7291
-26	108600	4	24550	34	7016
-25	102900	5	23460	35	6752
-24	97490	6	22430	36	6500
-23	92430	7	21450	37	6258
-22	87660	8	20520	38	6026
-21	83160	9	19630	39	5805
-20	78910	10	18790	40	5592
-19	74910	11	17980	41	5389
-18	71130	12	17220	42	5193
-17	67570	13	16490	43	5006
-16	64200	14	15790	44	4827
-15	61020	15	15130	45	4655
-14	58010	16	14500	46	4489
-13	55170	17	13900	47	4331
-12	52480	18	13330	48	4179
-11	49940	19	12790	49	4033
-10	47540	20	12260	50	3893
-9	45270	21	11770	51	3758
-8	43110	22	11290	52	3629
-7	41070	23	10840	53	3504
-6	39140	24	10410	54	3385
-5	37310	25	10000	55	3270
-4	35570	26	9605	56	3160
-3	33930	27	9227	57	3054
-2	32370	28	8867	58	2952
-1	30890	29	8523	59	2854

Table 1.2 Resistance values versus temperature of the CNR 1's thermistor.

The temperature sensor is located in the CNR 1 body. It will not measure the exact temperature of the CG 3, unless the whole instrument is in thermal equilibrium. Errors however are minimised in the design by making solid metal connections between the sensors and the temperature sensor. At all times the temperature sensor will give a very good approximation of the CG 3 temperature, and at all times the deviation between the temperatures of the two CG 3's will be small.

Relatively small errors occur when the CNR 1 is not in thermal equilibrium. This happens for example when the heater is on, or when the sun is shining. When the heater is on, the largest expected deviation between real sensor temperature and Pt-100 reading is 2 degrees. This results in a worst case error for the CG 3 of 10 Watts per square meter. When the sun is shining, the largest expected deviation between real sensor temperature and Pt-100 reading is again 2 degrees. This results in a worst case error for the CG 3 of 10 Watts per square meter.

The Pt-100 will not give a good indication of ambient air temperature; at 1000 Watts per square meter Solar Radiation, and no wind, the instrument temperature will rise approximately 12 degrees above ambient temperature.

The offsets of both pyranometers and pyrgeometers might be larger than 10 Watts per square meter if large temperature gradients are forced on the instrument (larger than 5 K/hr). This happens for example when rain hits the instrument. The occurrence of this can be detected using the Pt-100 readout. It can be used as a tool for quality assurance of your data.

#### 1.1.2.4 Calculation of the albedo for solar radiation

The albedo is the ratio of incoming and reflected Solar radiation. It is a figure somewhere between 0 and 1. Typical values are 0.9 for snow, and 0.3 for grassland. To determine albedo, the measured values of the two CM 3's can be used. The CG 3's are not involved, as they do not measure Solar radiation. Do not use measured values when solar elevation is lower than 10 degrees above the horizon. Errors in measurement at these elevations are likely and thus yielding unreliable results. This is due to deviations in the directional response of the CM 3's.

$$\text{Albedo} = (E \text{ lower CM 3}) / (E \text{ upper CM 3}) \quad (1.3)$$

In the above formula, E is calculated according to formula 1.1. Albedo will always be smaller than 1. Checking this can be used as a tool for quality assurance of your data. If you know the approximate albedo at your site, the calculation of albedo can also serve as a tool for quality control of your measured data at this specific site.

#### 1.1.2.5 Calculation of the Net Solar radiation

Net Solar radiation is the incoming Solar Radiation minus the reflected solar radiation. It equals the solar radiation that is absorbed by the earth's surface.

$$\text{Net Solar radiation} = (E \text{ upper CM 3}) - (E \text{ lower CM 3}) \quad (1.4)$$

In this formula E is calculated according to formula 1.1. Net Solar radiation will always be positive. Checking this can be used as a tool for quality assurance of your measured data.

Calculation of the Net Far Infrared radiation, soils temperature and sky temperature

Net Far Infrared radiation is, like Net Solar radiation, the part that contributes to heating or cooling of the earth's surface. In practice most of the time, Net Far Infrared radiation will be negative.

$$\text{Net Far Infrared radiation} = (E \text{ upper CG 3}) - (E \text{ lower CG 3}) \quad (1.5)$$

In this formula E is calculated according to formula 1.2. From this equation the term with T cancels.

The E measured with the CG 3, actually represents the irradiance of the sky (for the upward-facing CG 3) or the ground (for the downward-facing CG 3). Assuming that these two, ground and sky, behave like perfect blackbodies (actually this is only in theory), one can calculate an effective "Sky temperature" and an effective "Ground temperature".

$$\text{Sky temperature} = ((E \text{ upper CG 3}) / 5.67 \cdot 10^{-8})^{1/4} \quad (1.6)$$

$$\text{Ground temperature} = ((E \text{ lower CG 3}) / 5.67 \cdot 10^{-8})^{1/4} \quad (1.7)$$

As a rule of thumb, for ambient temperatures of about 20 degrees Celsius, one can say that one degree of temperature difference between two objects results in a 5 Watts per square metre exchange of radiative energy (infinite objects):

1 degree of temperature difference = 5 Watts per square metre (rule of thumb)

### 1.1.2.7 Calculation of the Net (total) radiation

In the 4 Separate Components Mode, Net radiation, NR, can be calculated using the individual sensor measurement results:

$$NR = (E \text{ upper CM 3}) + (E \text{ upper CG 3}) - (E \text{ lower CM 3}) - (E \text{ lower CG 3}) \quad (1.8)$$

Where E is the irradiance that is calculated for the CM 3 according to equation 1.1, for the CG 3 according to equation 1.2. the terms with T cancel from this equation.

### 1.1.3 Using the CNR 1 in the Net Radiation Mode (NRM)

Working in the NRM one only measures the Net radiation. This is done by subtracting the measured values of the lower sensors from those of the upper sensors. Making a soldered hardware connection of the electrical cables can do this. This is possible due to the fact that the sensor sensitivities are matched. The proper way to connect the hardware is indicated in figure 1.1. The Pt-100 does not have to be used because the temperature correction cancels when subtracting the lower CG 3 measurement results from those of the upper CG 3 (assuming that the temperatures of the opposite CG 3's are equal).

It should be realised that using the CNR 1 in this way, a large amount of information is lost, and also the possibilities of checking the validity, as well as the quality of the measured data, can not be utilised.

#### 1.1.3.1 Calculation of the Net (total) Radiation

When the sensors are connected in the way that is depicted in figure 1.1, the hardware performs the calculation of addition of the upper sensor irradiations and subsequent subtraction of the lower sensor irradiations. The net radiation, NR, can be calculated:

$$NR = V/C \quad (\text{in Net Radiation Mode only}) \quad (1.9)$$

Where V is the voltage generated by the CNR 1, and C is the CNR 1's calibration factor.

### 1.1.4 Using the heater

**Notice:** whenever the heater is used, the heating may cause errors in the measurement of the sensor temperature (see 1.1.2.3.) (Two degrees typical) and zero offsets in the CM 3 (10 Watts per square metre typical). Under most conditions the accuracy that is gained by heating will be larger than the errors that are introduced by heating.

In both the CM 3 and CG 3, thermal sensors are used. These sensors in principle measure a heat flow. For optimal performance, these sensors should be at equilibrium with the ambient air. Heating the sensor disturbs this equilibrium. This will give rise to zero offsets particularly in the CM 3. A typical value under conditions with no wind is 10 Watts per square metre. **Therefore heating should only be done if absolutely necessary.** CG 3 is less sensitive to this. Offset values for CG 3 cannot be determined, and therefore are not specified.

There is one major reason for heating: avoiding water deposition on the CG 3 window and on the CM 3 dome. In case of dew deposition on the CG 3 window, the dew will ultimately obstruct the Far Infrared radiation completely, causing a signal close to zero. In the case of rain, this will probably not lead to significant errors, because with an overcast sky the signal is close to zero anyway. The case of dew deposition is far more significant. Dew deposition will probably take place under conditions with large Far Infrared irradiation from the pyrgeometer detector to the clear sky, typically minus (-) 100 Watts per metre square. Under conditions where clouds or wind are present, dew is less likely to occur. A situation where dew depositing on the window of the CG 3, causing a signal of -100 Watts per square metre to drop to zero, is certainly significant. If heating can avoid this, it certainly should be done because all errors that are described above are much smaller than the gain in accuracy of 100 Watts per metre square.

For decisions about heating one can make the following diagram:

12 VDC, 6 VA available?	not available	Do not heat
	available	consider options below
clock and relay available?	not available	heat all day, all night
	available	heat from 1 hour before sunset until one hour after sunrise.

The maximum allowable power for the heater is 50 VA. In case of snow or frost one might also consider heating at a higher level than the usual 6 VA. Heating at 20 VA will melt snow in most cases. 20 VA can be reached at 22 Volts. During high power heating, measurement accuracy cannot be specified. You are advised to reject measured data readings during this high power heating.

If lower voltage is available, one might consider heating at a lower power. The 6 VA is designed for extreme conditions. 2 VA is sufficient for moderate conditions.

Time needed for reaching a stable instrument temperature when heating is about 60 minutes.

## 1.2 CNR 1 PERFORMANCE AND MEASUREMENTS UNDER DIFFERENT CONDITIONS

Below, table 1.3, shows an indication of what one might typically expect to measure under different meteorological conditions.

The first parameter is day and night. At night, the Solar radiation is zero. The second column indicates if it is cloudy or clear. A cloud acts like a blanket, absorbing part of the Solar radiation, and keeping Net Far Infrared radiation close to zero. The third parameter is ambient temperature. This is included to show that the "sky temperature" (column nine) tracks the ambient temperature. Under cloudy conditions this is logical; cloud bases will be colder than the ambient temperature at instrument level, the temperature difference depends roughly on cloud altitude.

Under clear sky conditions it is less obvious that sky temperature "adjusts" to the ambient temperature. This can roughly be attributed to the water vapour in the air, which is a major contributor to the Far Infrared radiation.

It is assumed that when ambient temperature varies, the Net Far Infrared radiation remains roughly the same, independent of ambient temperature. The resulting measured values of the CG 3's and CM 3's are stated in columns 4 to 7. These are indicative figures only, they depend strongly on other circumstances; the CG 3 results, of course, change with the sensor temperature. This is indicated in column 8. During the day, the Pt-100 reading may rise due to solar heating, up to 10 degrees above ambient temperature. During the night, the sensor temperature may be lower than the ambient temperature due to Far Infrared radiative cooling. The latter two effects do not influence the end result of the calculations of Sky T and ground T. Therefore they are not taken into account in the table. Actually in column 4 one might expect to see "0 to -50" for all positions that are showing "0", in column 5 the "0" values may in reality be "-20 to +20". The resulting sky temperature is indicated in column 9. Under cloudy conditions this sky temperature is equal to ambient temperature. Under clear conditions the sky temperature is lower than the ambient temperature.

The ground temperature in column 10 is assumed to be equal to the ambient temperature. In practice it may be higher during the day, due to solar heating. Ground temperature may be lower than ambient during the night, due to Far Infrared radiative cooling. The sky and the ground temperature can be calculated from the measured values of the sensors using formulas 1.6 and 1.7.

day night	Cloudy clear	+20 °C - 20 °C	CG 3 Up	CG 3 low	CM 3 up	CM 3 low	Pt 100	sky T	ground T
d	cloud	20	0	0	0-500	0-150	20	20	20
d	cloud	-20	0	0	0-500	0-150	-20	-20	-20
d	clear	20	-100*	0	0-1300	0-400	20	1*	20
d	clear	-20	-100*	0	0-1300	0-400	-20	-53*	-20
n	cloud	20	0	0	0	0	20	20	20
n	cloud	-20	0	0	0	0	-20	-20	-20
n	clear	20	-100***	0	0**	0	20	1***	20
n	clear	-20	-100***	0	0**	0	-20	-53***	-20

Table 1.3 Typical output signals of CNR 1 under different meteorological conditions. Explanation can be found in the text.

\* Values may suffer from the so-called window heating offset; the sun heats the pyrgeometer window causing a measurement error of + 25 Watts per square metre (maximum).

\*\* Values may suffer from negative Infrared offsets, caused by cooling off of the CM 3 dome by Far Infrared radiation. The maximum expected offset value is 15 Watts per square metre.

\*\*\* Values may suffer from dew deposition. This causes the CG 3-up values to rise from - 100 to 0 Watts per square metre.

### **1.3 AIRBORNE USE OF CNR 1**

Net radiometers are often used in aircraft and balloons. Although CNR 1 was not designed for this, it can be used in aircraft and balloons bearing in mind the specifications of static pressure and offsets caused by temperature gradients.

CNR 1 has been tested for static pressure to 0.2 bar. For this condition it is completely sealed. This is a unique specification, which makes the instrument more suitable for use in airborne environment than other competing instruments. Use out of specification can result in leakage of water, which might affect the instrument. For temperature gradients, we suggest to let the instrument stabilise until the gradient is smaller than 5K/hr. Under these conditions the offsets of the sensors are sufficiently small. Larger temperature gradients are permissible as long as one looks at the net radiation only, and not at the individual instrument readings. In this case temperature gradient offsets of the upper and lower sensors cancel.

### **1.4 QUALITY ASSURANCE OF DATA**

Because of the fact that separate sensors are used in the CNR 1, there are possibilities to check the quality of the data by analysing the signals. For this, one can use the measurement results of the temperature, the albedo and the net-solar radiation. If the values that are obtained for these quantities exceed certain values, this can be an indication that something is wrong. For more details we refer to the paragraphs 1.1.2.3, 1.1.2.4 and 1.1.2.5.





## 2 SENSOR PROPERTIES

The CNR 1 consists of two pyranometers, model type CM 3, for measuring solar radiation, and of two pyrgeometers, model type CG 3, for measuring Far Infrared radiation. CNR 1 properties are discussed in chapter 2.1, CM 3 properties are discussed in chapter 2.2, CG 3 properties are discussed in chapter 2.3.

### 2.1 PROPERTIES OF THE CNR 1 NET-RADIOMETER

The properties of CNR 1 are mainly determined by the properties of the individual sensors, both the CM 3's and CG 3's. These are discussed in the following chapters. The combination of these sensors offers the advantage of accuracy, robustness, and the possibility to evaluate the quality of the measured data.

Generally the accuracy of CNR 1 will be higher than that of competitive Net-Radiometers. The main reason for this is that the solar radiation measurement performed by the CM 3 is accurate, and offers a traceable calibration. Due to the fact that the Net Solar radiation can be very intense, 1000 Watts per square metre compared to a typical -100 for the Net Far Infrared radiation, the accuracy of the solar measurement is very critical. The CM 3 is an instrument that complies with the ISO second class specifications, and can be relied upon to give an accurate reading. Wind corrections, as applied by less accurate competitive instruments are not necessary. The robustness of the materials used implies that CNR 1 will not suffer from damage inflicted by birds. Figure 2.1 depicts a drawing of CNR 1. From a spectral point of view, the CM 3 and CG 3 are complementary. Together they cover the full spectral range: The CM 3 from 0.3 to 3 microns, and the CG 3 from 5 to 50 microns. The gap between these two produces negligible errors.

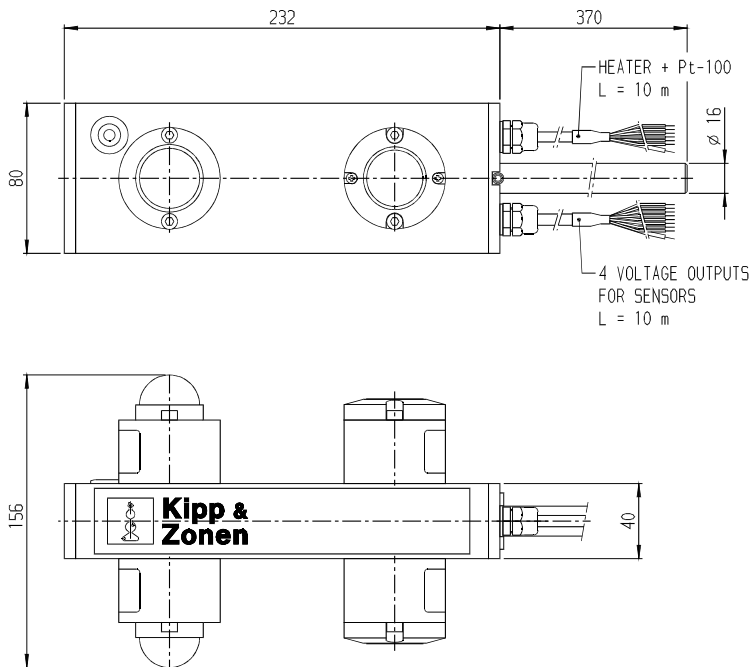


Figure 2.1 The dimensions of the CNR 1

### 2.1.1 List of specifications of the CNR 1

Specifications of Solar radiation measurement see CM 3 specifications

Specifications of Far Infrared radiation measurement see CG 3 specifications

Sensor sensitivities	:	All four sensors have equal sensitivity
Pt-100 sensor temperature measurement	:	DIN class A
Expected accuracy of the temperature measurement	:	+/- 2 K, under non-stable conditions with solar heating or heating by using the heating resistor.
Heating	:	resistor 24 Ohms, 6VA at 12 Volt
Expected worst case errors introduced by heating:	:	Pyranometer offset 10 Watt per metre square, Pt-100 error of +/- 2K.
Stabilisation time for heating	:	60 minutes
Operating temperature	:	-40 to +80 degrees Celsius
Requirements for data acquisition	:	
For Net Radiation only	:	one mV channel
For all four components	:	four mV signals, one Pt-100 channel plus software
Expected accuracy for daily totals	:	+/- 10 %
Cable length	:	10 m (each cable)
Weight	:	4 kg
Options	:	extended cables up to 100 metres 2 connectors, connecting the standard 10-meter cables (Radiometer and Pt-100/heater) to the extended cable

### 2.2 PROPERTIES OF THE CM 3 PYRANOMETER

A drawing of the CM 3 pyranometer is shown in figure 2.2.

The pyranometer consists of a thermopile sensor, a housing, a glass dome, and a cable. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation, and converts it to heat. The resulting heat flow causes a temperature difference across the thermopile. The thermopile generates a voltage output. In the casing of the CNR 1, the thermopile is again shunted with a resistor to adjust the sensitivity of each sensor, to that of the other sensors of CNR 1. The thermopile and the resistor determine most electrical specifications. The absorber paint and the dome determine spectral specifications. The thermopile is encapsulated in the housing in such a way that its field of view is 180 degrees, and that its angular characteristics fulfil the so-called cosine response. Pyranometers can be classified according to ISO 9060; the CM 3 complies with the second class specifications.

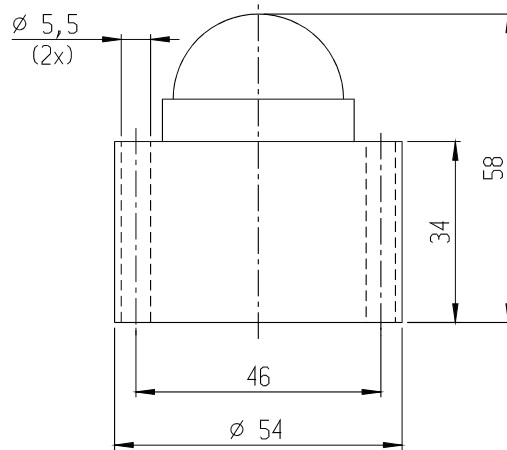


Figure 2.2 The dimensions of the CM 3 pyranometer

### 2.2.1 Electrical properties of the CM 3

The electrical circuit of the pyranometer is depicted in figure 2.3.

The nominal output resistance of the pyranometer is 125 ohms. This implies that the input impedance of the readout equipment should be at least 12.500 ohms, to give an error of less than 1 percent.

The cable can be extended, without problems, to a length of 100 metres; provided that the cable resistance remains within 0.1 percent of the input impedance of the readout equipment. The typical cable resistance is a 0.1 ohms per metre.

The electrical sensitivity of the thermopile changes with temperature. This change, however, is minimised. Calibration is done at 20 degrees Celsius, and is traceable to the World Radiometric Reference.

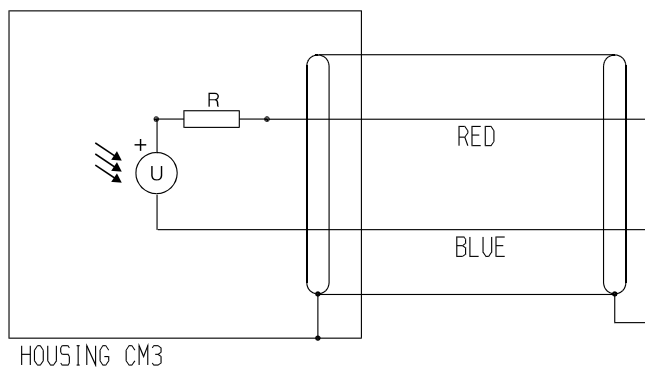


Figure 2.3 The electrical circuit of the CM 3 pyranometer

### 2.2.2 Spectral properties of the CM 3

The spectral properties of the pyranometer are mainly determined by the properties of the absorber paint and the glass dome. These are depicted in figure 2.4.

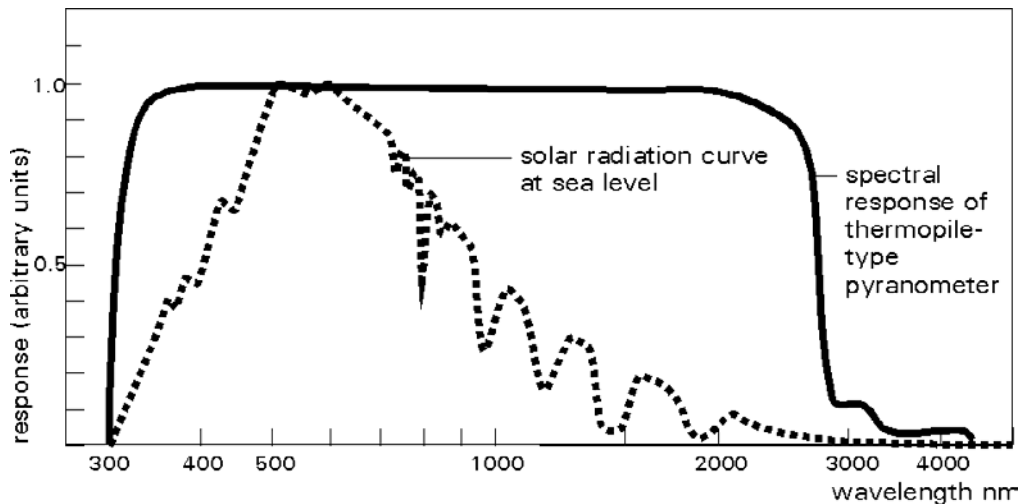


Figure 2.4 The spectral sensitivity of the pyranometer in combination with the spectrum of the sun, under a clear sky.

### 2.2.3 Directional / Cosine response of the CM 3

The measurement of solar radiation falling on a surface (also called irradiance or radiative flux) requires three assumptions: The surface is spectrally black, i.e. that it absorbs all radiation from all wavelengths. Its field of view is 180 degrees. The directional properties are similar to that of a blackbody. Another way of expressing these directional properties is to say that the sensor has to comply with the cosine response.

A perfect cosine response will show maximum sensitivity (1) at an angle of incidence of 0° (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90° (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence. Figure 2.5 shows the behaviour of a typical CM 3 pyranometer. The vertical axis shows the deviation from ideal behaviour, expressed in percentage of the ideal value.

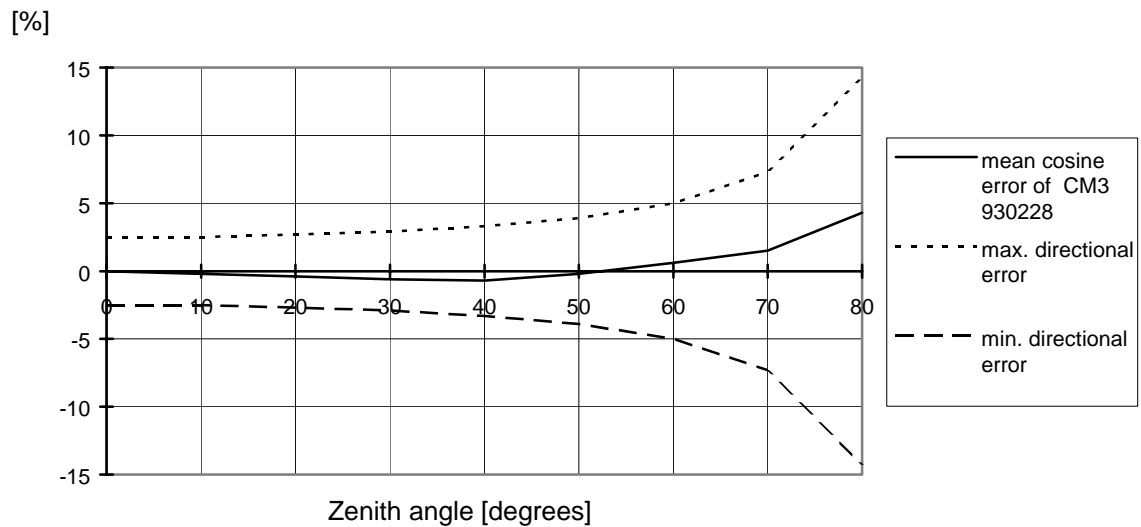


Figure 2.5 The directional response, or cosine response, of the CM 3 pyranometer: On the horizontal axis, the zenith angle is shown (0E zenith angle equals 90E angle of incidence). The vertical axis shows the deviation from the ideal cosine behaviour expressed in percents.

### 2.2.4 List of specifications of the CM 3

Specifications that are part of the ISO classification:

Response time 95%	:	18 s
Zero offsets 1 and 2	:	
1: 200 W/m <sup>2</sup> thermal radiation	:	+ 15 W/m <sup>2</sup>
2: 5 K/h change in ambient temperature	:	± 4 W/m <sup>2</sup>
Non-stability	:	± 1% change per year
Non-linearity	:	± 2.5% (0-1000 W/m <sup>2</sup> )
Directional error	:	± 25 W/m <sup>2</sup> at 1000 W/m <sup>2</sup>
Spectral selectivity	:	± 5 % (350-1500 nm)
Temperature dependence of sensitivity	:	± 6 % (-10 to +40°C)
Tilt response	:	± 2%
Overall ISO classification	:	second class

Other CM 3 specifications which are not part of the ISO requirement:

Sensitivity	:	10 - 35 μV/Wm <sup>-2</sup>
Impedance	:	125 Ohm (nominal)
Operating temperature	:	-40 °C to +80 °C
Spectral range	:	305-2800 nm (50% points)
Expected signal range for atmospheric application	:	0 - 50 mV
Expected accuracy for daily sums	:	± 10%

## 2.3 PROPERTIES OF THE CG 3 PYRGEOMETER

A drawing of the CG 3 pyrgeometer is depicted in figure 3.2.

The pyrgeometer consists of a thermopile sensor, a housing, and a silicon window. The thermopile is coated with a black absorbent coating. The paint absorbs the radiation and converts it to heat. The resulting heat flow is converted to a voltage by the thermopile. In the CNR 1's casing, shunt resistors are mounted to adjust the sensitivity of each sensor, to that of the other sensors in the radiometer.

Most electrical specifications are determined by the thermopile and the resistor.

Spectral specifications are determined by the absorber paint and the window. The window serves both as environmental protection and as a filter. It only transmits the relevant Far Infrared radiation, while obstructing the Solar radiation. The thermopile is encapsulated in its housing, so that its field of view is 150 degrees, and that its angular characteristics fulfil the so-called cosine response as much as possible, in this field of view.

The field of view, theoretically, should be 180 degrees. In practise however, it is limited due to the use of a flat window. This does not produce a large error because the missing part of the field of view does not contribute significantly to the total, and is compensated for during calibration.

There is no international standard that classifies pyrgeometers. Pyrgeometers have two specific properties that deserve special attention. The first is the so-called window-heating offset; the second is the influence of water deposition on the window.

### 2.3.1 Window heating offset

The window heating offset is a measurement error that is introduced by the heating of the CG 3 window by the sun. It only occurs during the day. During a sunny day, the upper CG 3 will suffer from this. This error cannot be avoided except by shading or ventilating. On a sunny windless day with a solar irradiance of  $1000\text{W/m}^2$ , an error of 25 Watts per square metre can be expected. The window will absorb part of the solar radiation and will heat up. As a result of this heating, heat will irradiate towards the thermopile. This results in a significant error source, in the Infrared range. This error is neglected, however, in the net radiation calculation. This is justified because the solar radiation is always dominant when this error occurs.

### 2.3.2 Water deposition on the pyrgeometer window

The second specific error source of a pyrgeometer is the substantial measurement error introduced as the result of water deposition on the window. Water will completely obstruct the transmission of Far Infrared radiation. Water deposition will occur when it rains, snows, or when dew is deposited. In the case of rain or snow, the resulting error is not very significant, mainly due to the fact that under these cloudy conditions, the CG 3 signal will be close to zero anyway. The cloud base temperature is generally close to ambient temperature. The conditions under which dew can form are much more likely to produce significant errors. A typical situation occurs at night, with a cloudless sky, low wind speeds, and high humidity (so-called clear, windless nights). Under these conditions, the upward-facing pyrgeometer signal is large, typically -100 Watts per square metre. When dew occurs, this reading can drop to zero, resulting in a 100 Watts per square metre error. Generally speaking this kind of error is too large, and if possible it should be avoided. Heating can prevent dew deposition with the CNR 1's incorporated heater. Heating will keep the instrument window above the dew point.

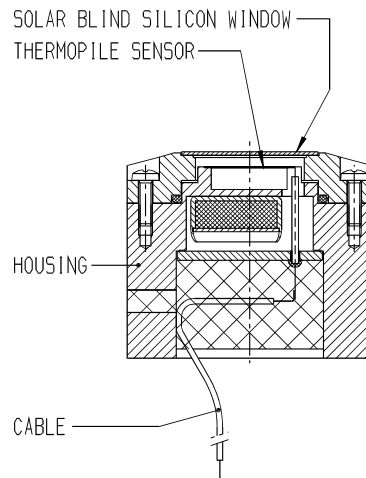


Figure 3.2 The CG 3 pygeometer

### 2.3.3 Electrical properties of the CG 3

The electrical circuit of the pygeometer is shown in figure 3.3.

The nominal output resistance of the pygeometer is 125 Ohms. This implies that the minimum input impedance of the readout equipment should be at least 12.500 ohms, in order to give an error of less than 1 percent.

The cable can be extended without any problems to a length of 100 metres, provided that the cable resistance remains within 0.1 percent of the input impedance of the readout equipment.

The electrical sensitivity of the thermopile changes with temperature. This change is however minimised. Calibration is done at 20 degrees Celsius. There is no international standard for the calibration of pygeometers.

The output of the CG 3 is a small voltage, in the mV range. It is proportional to the temperature difference between the CG 3 and the object that it faces. This implies that for calculation of the absolute quantity of Far Infrared radiation, that is emitted by the sky or the ground one also needs to take the CG 3's temperature into account. This temperature is measured by a Pt-100 that is incorporated in the body of CNR 1. The calculation of the Far Infrared irradiance is described in chapter 1.

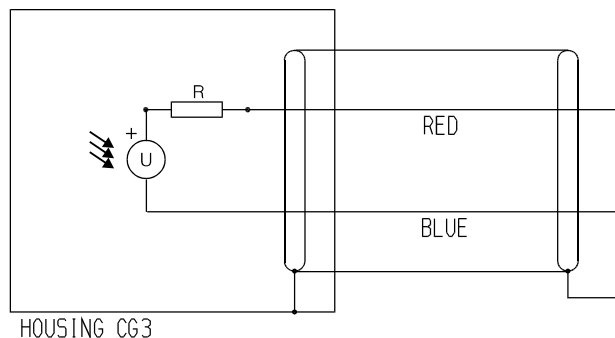


Figure 3.3. The electrical circuit of the CG 3 pygeometer



### 2.3.4 Spectral properties of the CG 3

The spectral properties of the pyrgometer are mainly determined by the properties of the absorber paint and the silicon window. The silicon window is coated on the inside with an interference filter, which blocks the solar radiation. The spectral characteristics of the CG 3 are depicted in figure 3.4.

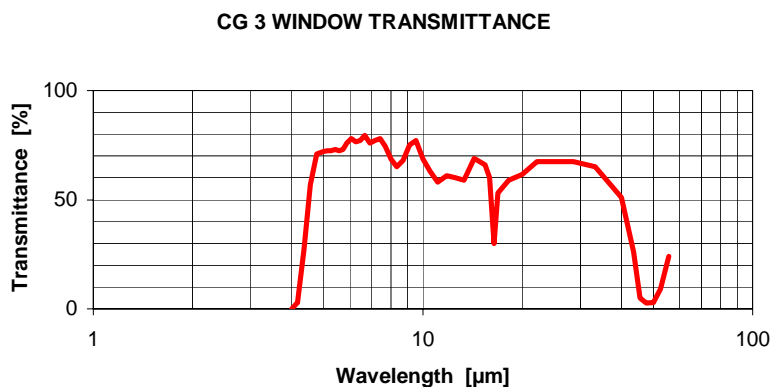


Figure 3.4 The spectral sensitivity of the pyrgometer window: Theoretically it equals the spectral selectivity of the total instrument.

### 2.3.5 Directional / Cosine response of the CG 3

The measurement of the Far Infrared radiation falling on a surface (also called irradiance or radiative flux) requires that the sensor has to comply with the cosine response.

A perfect cosine response will show a maximum sensitivity of (1) at an angle of incidence of 0° (perpendicular to the sensor surface) and zero sensitivity at an angle of incidence of 90° (radiation passing over the sensor surface). Between 90 and 0 degrees, the sensitivity should be proportional to the cosine of the angle of incidence.

For pyrgometers like the CG 3, there are no established measurement methods for determining the directional response. It is only based on theoretical considerations that one can say that it will comply with the ideal response, up to 75 degrees angle of incidence. This means that part of the sky is not seen. When calibrating the CG 3 at Kipp & Zonen, assumptions are made about the behaviour of the sky near the horizon. The errors that are produced by the assumptions that are made are small.

In view of the fact that it has never been measured, the directional response of the CG 3 is not specified.

### 2.3.6 List of specifications of the CG 3

Response time 95%	:	18 s
Non-stability	:	± 1% change per year
Non-linearity	:	± 2.5% (-250 to +250 W/m <sup>2</sup> )
Temperature dependence of sensitivity	:	± 6% (-10 °C to +40 °C)
Tilt response	:	max 3% when facing downwards
Field of view	:	150 degrees
Angular response	:	not specified
Sensitivity	:	5 - 18 µV/W/m <sup>2</sup>
Impedance	:	125 Ohm (nominal)
Operating temperature	:	-40 °C to +80 °C
Temperature range for specified behaviour	:	-10 °C to +40 °C
Measurement range	:	-250 to +250 W/m <sup>2</sup> (V/C)
Spectral range	:	4.5 to 42 µm
Expected signal range for atmospheric application	:	-4 to 4 mV
Expected accuracy for daily sums	:	± 10%
Window heating offset	:	max 25 W/m <sup>2</sup> at 1000 W/m <sup>2</sup> normal incidence solar radiation

## 2.4 PROPERTIES OF THE HEATER

The heaters purpose is to prevent dew deposition on the CG 3. It will prevent dew deposition on the CG 3 window, and thus promote measurement accuracy and reliability. It is designed to produce 6 Watts of power when used with a 12 VDC power supply. The resistance is approximately 24 Ohms. When it is recommended to use the heater, can be found in chapter 1.1.4.

Using the heater will produce errors, both in the CM 3 reading (zero offset, typical value of 10 Watts per square metre), and in the temperature reading of the Pt-100 (due to the location of the Pt-100 relative to the CG 3 and the heating resistor, typical value of 2 K). Generally these errors are small relative to the errors that would have been caused by water deposition. More information on this can be found in chapter 1.1.4 and 1.1.2.3

## 2.5 PROPERTIES OF THE PT-100 AND THE OPTIONAL THERMISTOR

The Pt-100 is a common temperature sensor. Essentially it is a resistor that is temperature dependent. The way it is connected is depicted in figure 1.1. The Pt-100 complies with the specifications of DIN, class A. A table stating the resistance values can be found in chapter 1.1.2.3.

Alternatively, as an option, one can order a thermistor, (nominal value is about 10k ohms at 25 degrees Celsius) which would replace the Pt-100. A table stating the resistance values can be found in chapter 1.1.2.3. The thermistor has a much larger resistance value than the Pt-100, also, the change in resistance with respect to temperature, in absolute terms, is greater. Therefore the cable resistance can be neglected, and only a 2-wire connection is used for the thermistor measurement, contrary to the 4-wire connection of the Pt-100.

### **3 CALIBRATION**

#### **3.1 CALIBRATION OF THE PYRANOMETERS**

The primary standard for pyranometers is the World Radiometric Reference. Reference pyranometers that are used at Kipp & Zonen are calibrated using the primary standard. The Kipp & Zonen CM 3 calibration is traceable to the World Radiometric Reference. Further reference conditions are as follows: temperature 20 degrees Celsius, irradiance 500 Watts per metre square, in the horizontal position. Each pyranometer has an individual calibration factor. The four individual calibration factors are trimmed to one and the same value. This final factor can be found on the calibration certificate, included with the instrument.

#### **3.2 CALIBRATION OF THE PYRGEOMETERS**

There is no primary standard for pyrgeometer measurements. The CG 3's in the CNR 1 are calibrated relative to the reference that is present at Kipp & Zonen. In turn this reference has been calibrated against a cold blackbody radiation source.

#### **3.3 RECALIBRATION OF PYRANOMETERS AND PYRGEOMETERS**

We suggest recalibration for all sensors, pyranometers, and pyrgeometers to be performed every two years by an authorised Kipp & Zonen calibration facility, or as an alternative, by letting a higher standard run parallel to it over a two-day period and then comparing the results. For comparison of pyranometers, one should use a clear day. For comparison of pyrgeometers, one should compare night time results. Deviations of more than 6% can be used to correct the calibration factors. When using the CNR 1 in the Net-Radiation Mode (creating one output signal) please bear in mind that the correction of the calibration factors necessitates incorporation of new shunt resistors in the CNR 1's body.

The recalibration of the CNR 1 is preferably done at Kipp & Zonen because of the capability to recalibrate CG 3 pyrgeometers, and the capability to install new shunt resistors.

#### **3.4 ADJUSTING THE TRIMMING RESISTORS**

The adjustment of the trimming (or shunt) resistors is necessary only if the calibration factor of one of the sensors has changed in such a way that it deviates significantly from the others. At Kipp & Zonen, a margin of +/- 1% is tolerated. See the electrical circuit diagram depicted in figure 2.3. Assuming that the individual sensor has been calibrated with a shunt resistor, and has a calibration constant C, and that the required calibration constant is C\*, C can be adapted by changing the shunt resistance from the original  $R_{shunt}$  to  $R^*_{shunt}$

Step by step procedure:

1. Calibrate with shunt resistance. The calibration constant is C.
2. Disconnect the original shunt resistor. Measure its value,  $R_{shunt}$ .
3. Measure the sensor resistance RE: To do this, block all light from the sensor, e.g. by using a cardboard box, so that the sensor does not generate a voltage output. For pyrgeometers darkness is not required, but rather thermal equilibrium between the inside of the box and the

sensor. Please perform the resistance measurement with both polarities (in this way errors caused by output voltages can be avoided). When polarities are changed (this means that + and - connections of the resistance meter have to be reversed), the average of these two readings can be used as the true value of RE.

- 4 The sensor can be considered to be a voltage source with an internal series resistance, RE. The shunt resistor, R<sub>shunt</sub>, will simply act as a voltage divider. With a known C, C\* and RE. One should choose a replacement shunt resistor R\*<sub>shunt</sub> according to the following formula (valid if R<sub>shunt</sub> is not zero).

$$R^*_{shunt} = R_{shunt} (C^* / (C (1 + RE/R_{shunt}) - C^*)) \quad (3.1)$$

Resistor values should be +/- 0.25 %. If R<sub>shunt</sub> is zero, a simpler equation is applicable:

$$R^*_{shunt} = RE ((C^*/(C^*-C)).$$

- 5 The chosen resistor must replace the old shunt resistor on the printed circuit board inside the CNR 1's body.
- 6 A recalibration, with new shunt resistors installed, serves as a final step in the quality assurance of the CNR 1.

### **3.5 CALIBRATION OF THE PT-100**

Please check the reliability of the Pt-100 measurement by doing a parallel measurement with another temperature sensor. This, for example, can be done by temporarily attaching a stick-on type thermocouple to the CNR 1's body, and then subsequently comparing the readout of the thermocouple with the readout of the Pt-100. The discrepancy, assuming that the thermocouple has a +/- 0.2 degrees accuracy, should be within +/- 0.7 degrees. If it is greater, the Pt-100 should be replaced.



## **4 INSTALLATION AND MAINTENANCE**

For measurement of the Net Radiation, it is most important that the instrument is located in a place that is representative of the entire region that one wishes to study.

When installed permanently, the net radiometer should be attached to its mounting platform with the rod that is attached to its body.

When installed on a mast, the preferred orientation should be such that no shadow is cast on the Net Radiometer at any time during the day. In the Northern Hemisphere this implies that the Net Radiometer should be mounted south of the mast.

It is suggested that the CNR 1 is mounted at a height of at least 1.5 metres above the surface, to avoid shading effects of the instruments on the soil and to promote spatial averaging of the measurement. If the instrument is  $H$  metres above the surface, 99% of the input of the lower sensors comes from a circular area with a radius of  $10 H$ . Shadows or surface disturbances with radius  $< 0.1 H$  will affect the measurement by less than 1%.

The Net Radiometer should be installed horizontally, using the level on the body of the CNR 1.

For installation in buildings or in solar energy applications, one will often have to mount the CNR 1 parallel to the surface that is being studied. This may be in a tilted, or a vertical position. The sensitivity of the radiometers will be affected, but only in a minor way. This is specified as the so-called tilt effect. From the specifications in chapter 2 one can see that the tilt effect (this is change in sensitivity) remains within 3 %.

The Net Radiometer is an all-weather instrument.

Once installed it needs little maintenance. It is suggested that one clean the windows and domes as part of a regular routine, using water or alcohol.

Recalibration is suggested every two years. More information on this can be found in chapter 3 on calibration.



## **5 TROUBLE SHOOTING**

This chapter describes what to do if there appears to be a problem. If the suspected problem concerns the heater or the Pt-100, please consult chapters 5.3 and 5.4. If the suspected problem concerns the radiometers, continue reading the text.

If there is no clue as to what may be the problem, start performing the following "upside-down test", which is a rough test for a first diagnosis. It can be performed both outdoors and indoors. Indoors, a lamp can be used as a source for both Solar and Far Infrared radiation. Outdoors one should preferably work with a solar elevation of more than 45 degrees (45 degrees above horizon) and of course under stable conditions (no large changes in solar irradiance, preferably cloudless) :

1. Measure the output ( in 4SCM or NRM ) in the normal position. Record the measured values when the signals have stabilised, i.e. after about 3 minutes.
2. Rotate the instrument 180 degrees, so that the upper and the lower sensors are now in the reverse orientation as to the previous position.
3. Measure the output once more. Record the measured values when the radiometers have stabilised.
4. Since of the all sensors are trimmed, the values in the rotated position should be equal in magnitude, only differing in sign. In a rough test like this, deviations of +/- 10 % should be tolerated. If deviations greater than this are encountered, the following tests might help.

### **5.1 TESTING THE CM 3**

As a first test we recommend that one check the sensor impedance. It should have a nominal value as indicated in the specifications. Zero, or infinite resistance indicates a failure in hardware connection.

Before starting the second test measurement, let the CM 3 rest for at least five minutes to let it regain its thermal equilibrium. For testing, set a voltmeter to its most sensitive range setting. Darken the sensor. The signal should read zero. Bear in mind that the response takes about one minute. Small deviations from zero are possible; this is caused by thermal effects like touching the pyranometer with your hand. The latter effect can be demonstrated by deliberately heating the CM 3 with your hand. Another cause might be the zero offset of the amplifier. When this is the case, the same offset will also be present when the amplifier is short-circuited with a 200 Ohm resistor. This is an amplifier error. This amplifier error should not be larger than 5 Watts per square metre. If the amplifier error is within specifications, proceed with the third test.

In the third test the sensor should be exposed to light. The signal should be a positive reading. Set the voltmeter range in such a way that the expected full-scale output of the pyranometer is within the full-scale input range of the voltmeter. The range can be estimated on theoretical considerations. (When the maximum expected radiation is 1500 Watts per square metre, which is roughly equal to normal outdoor daylight conditions, and the sensitivity of the pyranometer is 15  $\mu\text{V}$  per Watt per square metre, the expected output range of the pyranometer is 1500 times 15 which is equal to 22500  $\mu\text{V}$ , or 0.0225 Volts). One can calculate the radiation intensity by dividing the pyranometer output (0.0225 volts) by the calibration factor (0.000015 volt per watt per square metre). Still no faults found? Your pyranometer is probably doing fine.



## **5.2 TESTING OF THE CG 3**

It is assumed that the amplifier circuit is the same as the one used for CM 3, and that its zero offset is no more than a few watts per square metre, let us say 5 Watts per square metre just as an example, (see second test in 5.1).

The pyrgeometer, the mounting plate, and ambient air should be at the same temperature as much as possible. Let the CG 3 rest for at least five minutes to regain its thermal equilibrium. Set the voltmeter to its most sensitive range. To test if the CG 3 is working properly, we suggest putting your hand in front of the CG 3. The thermal radiation will cause CG 3 to generate a positive voltage when the hand's surface temperature is higher than the pyrgeometer temperature. The CG 3 will generate a negative voltage if the hand is colder. The signal is proportional to the temperature difference (see the rule of thumb of 1.1.2.6). The radiation that is emitted by the hand can be calculated by dividing the pyrgeometer output by the calibration factor, and subsequently correcting for the temperature, according to equation 1.2. Still no faults found? Your pyrgeometer is probably doing fine.

## **5.3 TESTING THE HEATER**

Using a meter, which measures resistance, can check the operation of the heater. If connected properly, the resistance of two opposite wires of the heater should measure about 8 ohms (this includes the cable resistance for the standard 10-meter cable). The cable resistance should measure about 0.1 ohms per metre cable. An infinite resistance reading indicates the likelihood of a broken wire, or cable.

## **5.4 TESTING THE PT-100**

Using a meter, which measures resistance, can check the operation of the Pt-100. If connected properly, the resistance of two opposite wires of the Pt-100 should measure about 100 ohms (this includes the cable resistance for the standard 10-meter cable). The cable resistance should measure about 0.1 ohms per metre cable.

## **6 DELIVERY**

Check the contents of the shipment for completeness (see below) and note whether any damage has occurred during transport.

If there is damage, a claim should be filed with the carrier immediately. In this case, or if the contents are not complete, your dealer should be notified in order to facilitate the repair or replacement of the instrument.

The CNR 1 Net-Radiometer delivery will include the following items:

A delivery includes:

- One CNR 1
- One calibration certificate
- One instruction manual

### **Unpacking**

Keep the original packaging for later shipments (e.g. recalibration)!

Although all sensors are weatherproof and suitable for harsh ambient conditions, they do partially consist of delicate mechanical parts. It is recommended to use the original shipment packaging to safely transport the equipment to the measurement site.



**7 ACCESSORIES**

Ventilation system CNR 1	0340 710
Ventilation system CNR 1 with heater	0340 711



## **RECALIBRATION SERVICE**

### **Pyranometers, UV-meters, Pyrgeometers & Sunshine duration meters**

Kipp & Zonen solar radiation measurement instruments comply with the most demanding international standards. In order to maintain the specified performance of these instruments, Kipp & Zonen recommends calibration of their instruments at least every two years.

This can be done at the Kipp & Zonen factory. Here, recalibration to the highest standards can be performed at low cost. Recalibration can usually be performed within four weeks. If required, urgent recalibration can be accomplished in three weeks or less (subject to scheduling restrictions). Kipp & Zonen will confirm the duration of recalibration at all times. Please note that special quantity recalibration discounts are available.

For your convenience we added three fax forms to schedule the recalibration of your instrument(s) at Kipp & Zonen.



**NAME** :  
**COMPANY/INSTITUTE** :  
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**COUNTRY** :  
**PHONE** :  
**FAX** :

**I would like to receive a price list for recalibration**

**I would like to submit my instruments for recalibration**

Type/Model:	Qty:	Requested delivery time
		I intend to send the instruments to Kipp & Zonen on: ...../...../.....
		I would like to receive the instrument(s) back on: ...../...../.....

Conformation by Kipp & Zonen	
<input type="checkbox"/>	Yes, the dates are acceptable to us
<input type="checkbox"/>	No, unfortunately the dates do not fit into our calibration schedule. We suggest the following dates: ...../...../..... ...../...../.....

**Fax +31-15-2620351**

Or mail to:

**Kipp & Zonen P.O. Box 507 2600AM**  
**Delft The Netherlands**





**NAME** :  
**COMPANY/INSTITUTE** :  
**ADDRESS** :  
**POSTCODE +CITY** :  
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**Delft The Netherlands**





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SINCE 1830

Our customer support remains at your disposal for any maintenance or repair, calibration, supplies and spares.

Für Servicearbeiten und Kalibrierung, Verbrauchsmaterial und Ersatzteile steht Ihnen unsere Customer Support Abteilung zur Verfügung.

Notre service 'Support Clientèle' reste à votre entière disposition pour tout problème de maintenance, réparation ou d'étalonnage ainsi que pour les accessoires et pièces de rechange.

Nuestro apoyo del cliente se queda a su disposición para cualquier mantenimiento o la reparación, la calibración, los suministros y reserva.

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