INSTRUCTION MANUAL

CM 21 / CM 31

PYRANOMETER

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Kipp & Zonen

CE

Declaration of Conformity

According to EC guidline 89/336/EEC

We **KIPP & ZONEN B.V.**
Röntgenweg 1
2624 BD Delft

declare under our sole responsibility that the product

Type : **CM21**
Name: **PYRANOMETER**

to wich this declaration relates is in conformity with the following standards

Imissions		
EN 50082-1	Groupstandard	
IEC 1000-4-2	IEC 801-2	8 kV
IEC 1000-4-3	IEC 801-3	3 V/m
IEC 1000-4-4	IEC 801-4	1 kV
Emissions		
EN 50081-1	Groupstandard	
EN 55022		

following the provisions of the directive.

KIPP & ZONEN B.V.
Röntgenweg 1
2624 BD Delft
Product management

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GENERAL INFORMATION

Introduction

The pyranometer CM 21 is designed for measuring the irradiance (radiant-flux, Watt/m^2) on a plane surface, which results from the direct solar radiation and from the diffuse radiation incident from the hemisphere above.

Because the CM 21 exhibits no tilt dependence, it can measure solar radiation on surfaces inclined as well.

In the inverted position reflected solar radiation can be measured.

For measuring the diffuse component of solar radiation only, the direct solar component can be shielded semi-automatically from the pyranometer by the Kipp & Zonen shadow ring CM 121.

As the CM 11 pyranometer, the CM 21 complies with the specifications for 'secondary standards', the best of three classes, as published in the 'Guide to meteorological Instruments and Methods of Observation', Fifth edition, 1983, of the World Meteorological Organization (WMO) - Geneva - Switzerland.
The WMO classification list is adopted, improved and extended by the International Standard Organization ISO and published as ISO 9060.
This standard is one of a series of standards specifying methods and instruments for the measurement of solar radiation.
In this manual the specifications of accuracy are listed according the ISO list.
Some specifications of the CM 21, however, are twice as good as required.

The special features of the CM 21 are:
- High sensitivity, which could result in lower specifications for the data acquisition system.
- Low impedance, which reduces sensitivity for interference and noise.
- Low temperature response, which is an advantage when working under extreme climatological conditions.
- Low non-linearity.

The CM 31 pyranometer essentially consists of a CM 21 sensor combined with quartz (Infrasil II) domes. This not only affects spectral characteristics. Because of the fact that the thermal conductivity of quartz is much higher than that of glass, zero offsets are strongly reduced also.

SPECIFICATIONS OF PYRANOMETER CM 21

Performance

Response time time for 95 % response	:	< 5 s
Zero off-set a)response to 200 $W.m^{-2}$ net thermal radiation (ventilated)	:	+ 7 W m^{-2}
b)response to 5 K h^{-1} change in ambient temperature	:	± 2 W m^{-2}
Non-stability percentage change responsitivity per year	:	± 0.5 %
Non-linearity percentage deviation from the responsitivity at 500 Wm^{-2} due to the change in irradiance within 100 Wm^{-2} to 1000 Wm^{-2}	:	± 0.25 %
Directional response for beam radiation The range of errors caused by assuming that the normal incidence responsitivity is valid for all directions when measuring from any direction a beam radiation whose normal incidence irradiation is 1000Wm^{-2}	:	± 10Wm^{-2}
Spectral selectivity percentage deviation of the product of spectral absorptance and spectral transmittance from the corresponding mean within 0,35 μm and 1,5 μm	:	± 2%
Temperature response percentage deviation due to change in ambient temperature within an interval of -20 to +50 °C, relative to 20 °C.	:	± 1%

Tilt response percentage deviation from the responsivity at 0° tilt (horizontal) due to change in tilt from 0° to 90° at 1000$W.m^{-2}$ irradiance	:± 0,25%
Viewing angle	:2π sr
Irradiance	:0 - 1400 W/m^2 (max.4000W/m^2)
Spectral range	:305-2800 nm (50% points) 335-2200 nm (95% points)
Sensitivity	:between 7 and 25 μV/Wm^{-2}
Impedance	:40-100 Ohm

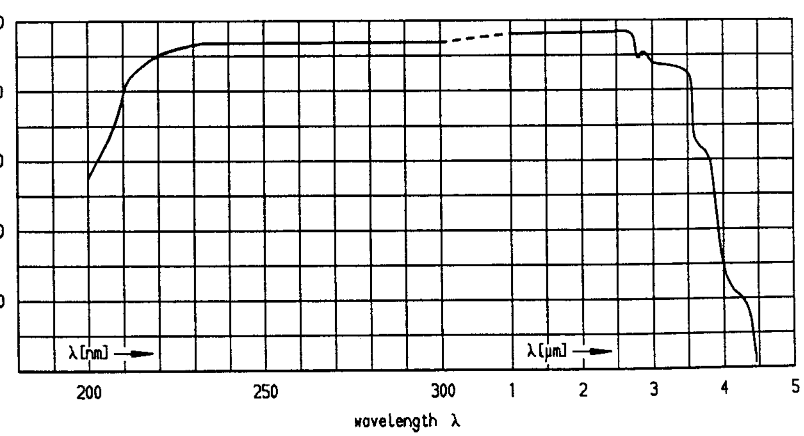
Construction

Receiver paint	:Carbon black
Glass domes	:Schott K5 optical glass 2 mm thick, 30 mm and 50 mm outer diameter
Desiccant	:Silicagel
Spirit level	:Sensitivity 0.1 degree (bubble half out of the ring) Coincide with base of the instrument. Detector surface and base are coplanar within 0.1°
Materials	:Anodized aluminium case Stainless steel screws in stainless steel bushes. White plastic screen of ASA Drying cartridge PMMA
Weight	:830 g
Cable length	:10 m
Dimensions	:See figure 3

PECIFICATIONS OF PYRANOMETER CM 31

he specifications of the pyranometer CM 31 are he same as those of the CM 21, with the following xceptions:

pectral range	:	200-4000 nm (50% points) 290-3500 nm (95% points)
pectral electivity	:	max. 2% in the spectral range 300 to 3000 nm
ero off-set esponse to 200 Wm^{-2}	:	+ 4 Wm^{-2}
irectional response or beam radiation	:	5 Wm^{-2}
uartz domes	:	Infrasil II (see fig 1)



ansmittance of the CM 31 Infrasil II domes

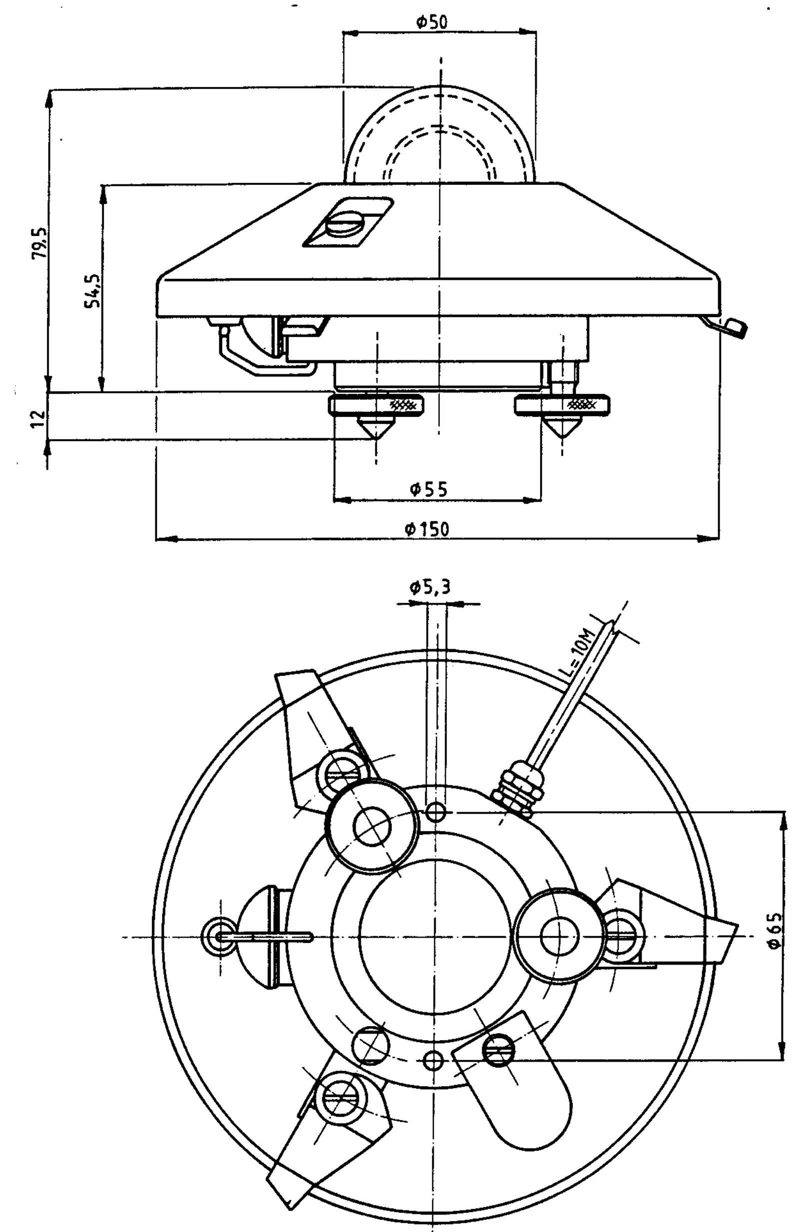


Fig. 3 Kipp & Zonen pyranometer CM 21 outline dimensions in mm.

INSTALLATION OF THE PYRANOMETER FOR MEASUREMENT OF GLOBAL RADIATION

Location

Ideally the site for the pyranometer should be free from any obstructions above the plane of the sensing element, and at the same time the pyranometer should be readily accessible to clean the domes and inspect the desiccator.

If this is not possible, the site should be chosen in such a way that any obstruction over the azimuth range between earliest sunrise and latest sunset should have an elevation not exceeding 5° (The apparent sun diameter is 0.5°).
This is important for an accurate measurement of the direct solar radiation. The diffuse (solar) radiation is less influenced by obstructions near the horizon. For instance, an obstruction with an elevation of 5° over the whole azimuth range of 360° decreases the downward diffuse solar radiation by 0.8% only.

It is evident that the pyranometer should be located in such a way that a shadow will not be cast on it at any time (for example, by masts or exhaust pipes).
Mind that hot (over 200 degrees centigrade) exhausted gas (streams) will produce radiation in the spectral range of the CM 21 Pyranometer.
The pyranometer should be far from light-coloured walls or other objects likely to reflect sunlight onto it.

Mounting

In principle no special orientation of the instrument is required.
The World Meteorological Organization recommends that the emerging leads are pointed to the nearest Pole, to minimize heating of the electrical connections.
However, when a polar diagram of the combined azimuth and cosine response is available, the pyranometer may be orientated so that the sun path lies in the low error region.

The pyranometer CM 21 is provided with two holes for 5 mm bolts, e.g. allen head bolts M5x60 or M5x65. The pyranometer should first be secured lightly with the bolts to a mounting stand or platform.
Accurate measurement of the global radiation requires the proper levelling of the thermopile surface. Level the instrument by turning the levelling screws to bring the bubble of the spirit level within the ring (mark). (For easy levelling first use the screw near the spirit level).
When the CM 21 is placed horizontally with the spirit level or when it is mounted with its base to a horizontal plane, the thermopile is horizontal within 0.1°. This causes a maximum azimuthal variation of + or -1% at a sun's elevation of 10°. By radiometrically levelling, the pyranometer can be placed horizontal more accurately. See Appendix IV.

The mounting stand temperature can vary over a wider range than the air temperature. Temperature fluctuations of the pyranometer body can produce offset signals. See Appendix II.
It is recommended to isolate the pyranometer thermally from the mounting stand, e.g. by placing it on its levelling screws. But keep an electric contact with earth to lead off current in the cable induced by lightning.

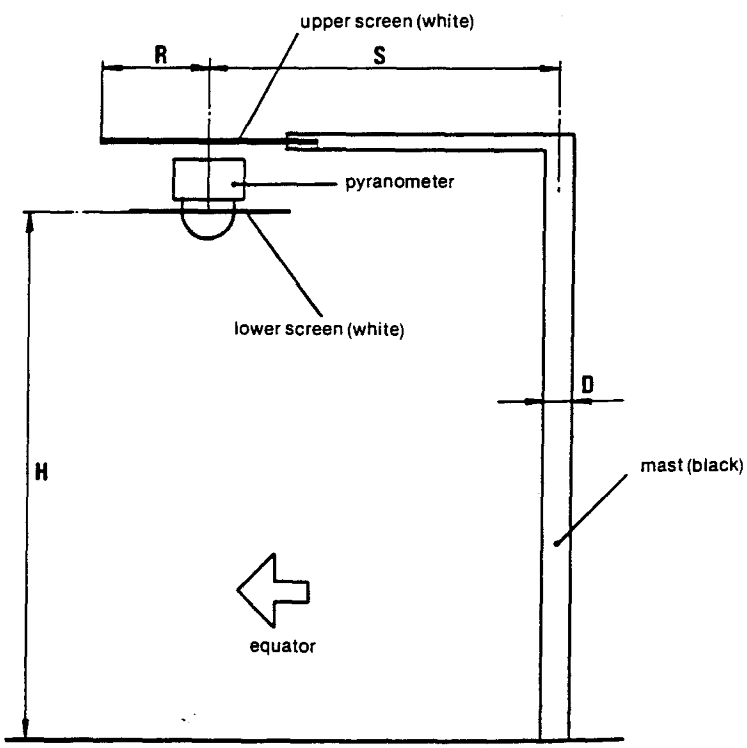
4. INSTALLATION FOR MEASUREMENT OF SOLAR RADIATION ON INCLINED SURFACES

See also 'installation for measurement of global radiation'.
It may be necessary to remove the levelling screws for easy orientation of the instrument parallel to the inclined surface. If the temperature of the mounting stand is expected to rise considerably (more than 10° C above air temperature), then the body must be thermally isolated from the stand. This will promote a thermal equilibrium between domes and body and decrease zero offset signals.
The pyranometer CM 21 shows no tilt effect up to irradiances of 1400 W/m^2.

INSTALLATION FOR MEASUREMENT OF REFLECTED SOLAR RADIATION

In the inverted position the pyranometer measures reflected global radiation. According to the WMO the height should be 1-2 m above a surface covered by short cut grass.

The mounting device should not interfere too much with the field of view of the instrument. A construction as in fig. 4 is suitable.
The upper screen prevents excessive heating of the pyranometer body by the solar radiation, and if large enough, it keeps free the lower screen of precipitation. The lower screen prevents direct illumination of the domes by the sun at sunrise and sunset.



Arrangement to measure reflected global radiation.

Offset signals generated in the pyranometer by thermal effects (see Appendix II) are a factor of 5 more disturbing in the measurement of the reflected radiation due to the lower irradiance level.
The mast in the construction of fig. 4 intercepts a fraction $D/2\pi S$ of the radiation coming from the ground.
In the most unfavourable situation (sun at zenith) the pyranometer shadow decreases the signal with a part R^2/H^2.

6. INSTALLATION FOR MEASUREMENT OF DIFFUSE RADIATION

For measuring the sky radiation, the direct solar radiation is best intercepted by a small metal disk. The shadow of the disk must cover the pyranometer domes completely. However, to follow the sun's apparent motion, a power driven equatorial device is necessary.

Simpler is the use of a shadow ring. It intercepts the direct solar radiation some days without readjustment, but also a proportion of the diffuse sky radiation. Corrections for this to the record are necessary.
Kipp & Zonen supplies a universal shadow ring CM 121 for all latitudes. See figure 2. In the manual of the CM 121 more installation and operating instructions are given.

6.1 Under water

The CM 21 pyranometer is in principle watertight. However, the hemispherical air-cavity under the dome(s) acts as a negative lens. The parallel beam of direct solar radiation becomes divergent after the passage of the outer dome, known as "defocussing effect".
Consequently the intensity at the sensor is much less than outside the pyranometer. The sensitivity figure is not valid in this case.

ELECTRICAL CONNECTION

The CM 21 is provided with a 5 m cable with shield and three leads.
The colour code is: red = plus
blue = minus
white = case

The shield is isolated from the case, so no shield-current can exist. Shield and white lead may be connected to the same ground at the readout equipment. The cable must be firmly secured to minimize spurious response during stormy weather (Pressing the cable produces voltage spikes, a tribo electric effect and capacitance effect).
The CM 21 and CM31 cables are made of selected materials with minimal tribo electric effect.
Take care that the terminals '+' and '-' at a connection box have the same temperature, to prevent thermal EMF's. A box or connector with metal outer case is advised.
Looking at the circuit diagram of fig. 5, it is clear that the impedance of the readout equipment is loading the thermistor circuit and the thermopiles. It can increase the temperature dependency of the pyranometer. The sensitivity is affected more than 0.1% when the load resistance is under 60 kOhm. For this reason we recommend the use of readout equipment with input impedances of 60 kohm or more such as potentiometric recorders, digital voltmeters, etc. The CC12 and CC14 solar integrators and most chart recorders of Kipp & Zonen meet these requirements. Long cables may be applied, but the cable resistance must be smaller than 0.1% of the impedance of the readout equipment.

Kipp & Zonen supplies shielded extension cable up to lengths of 200 m which is coupled by waterproof connectors to the CM 21 cable. The lead resistance is 8 Ohm/100 m.

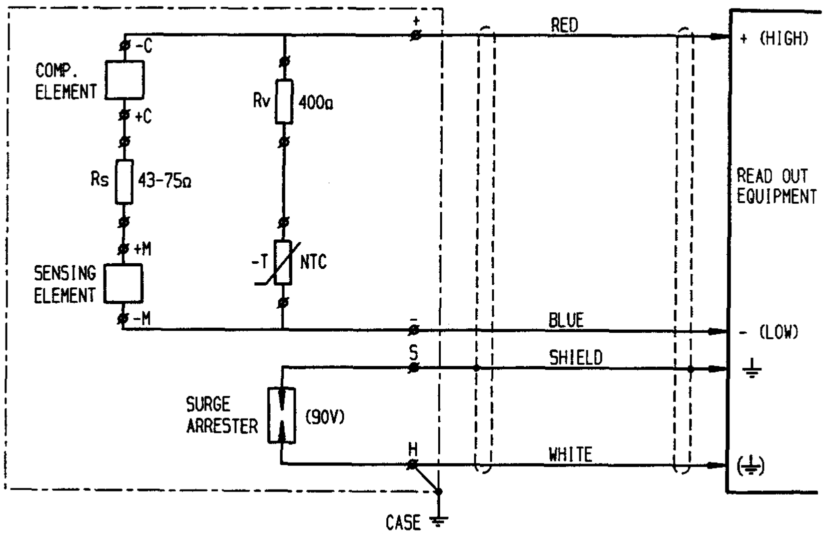
It is evident that application of attenuator circuits to modify the calibration factor is not recommended because the temperature response is also affected then. However, recorders with a variable voltage range can be set so that the result can be read directly in W/m^2.

A considerable input bias current of the readout equipment can produce a voltage of several microvolts across the impedance of the pyranometer. The correct pen's zero can be adjusted with a resistance replacing the pyranometer impedance at the input terminals.

The pyranometer can be connected to a computer or data acquisition system as well. A low voltage analog input module with AD-converter must be available then. The span and resolution of the analog/digital converter in the module must allow a system sensitivity of about 1 bit per W/m^2. More resolution is not necessary during outdoors solar radiation measurements, because pyranometers exhibit offsets up to + or - 2 W/m^2 due to lack of thermal equilibrium.

For amplification of the pyranometer signal many amplifier types are for sale in the temperature measurement branch.

A surge arrester is installed to lead off induced lightning current to the case. It is recommended to ground the case for this reason. The surge arrester is noble gas filled, has infinite impedance and recovers after breakdown. Breakdown voltage is 90 V. Peak pulse current is 10 kA.



Circuit diagram of Kipp & Zonen pyranometer CM 21/31 and connection to readout equipment.

8. MAINTENANCE AND OPERATING

Once installed the pyranometer needs little maintenance. The outer dome must be inspected at regular intervals and cleaned regularly, preferably every morning. At clear windless nights the outer dome temperature of horizontally placed pyranometers will decrease, even till the dew point temperature of the air, due to IR radiation exchange with the cold sky. (The effective sky temperature can be 30° C lower than the ground temperature, which results in an infrared emission of - 150 W/m^2). In that case dew, glazed frost or hoar frost can be precipitated on the top of the outer dome and can stay there for several hours in the morning. An ice cap on the dome is a strong diffusor and increases the pyranometer signal drastically up to 50% in the first hours after sunrise.

In some networks, the exposed dome of the pyranometer is ventilated continuously by a blower to keep the dome above dewpoint temperature. Preheating of the air is not necessary in principle. The ventilation also decreases the sensitivity to thermal radiation (zero offset I) with a factor 2 or less.

When the blue silicagel in the drying cartridge is turned completely pink (normally after several months), it must be replaced by active material. Pink silicagel can be activated again in an oven at 130° C within several hours.

CALIBRATION

The ideal pyranometer should always have a constant ratio: voltage output / irradiance level (outside the instrument in the plane of the sensing element). This ratio is called sensitivity or responsivity.

The irradiance value can be simply computed by dividing the output signal of the pyranometer by its sensitivity figure, or by multiplication of the signal value with the reciprocal of the sensitivity figure. (Often called calibration factor).

The sensitivity figure of a particular pyranometer is an individual one. It is determined in the manufacturer's laboratory by comparison against a standard pyranometer. See Appendix III.
The standard pyranometer is calibrated outdoors regularly at a Radiation Centre. The spectral content of the laboratory lamp differs from the outdoors solar spectrum at the Radiation Centre of course. However, this has no consequences for the transfer of calibration, because standard and unknown pyranometer have the same black coating and glass domes.

The supplied sensitivity figure is valid for the following conditions: An ambient temperature of 20° C. For a horizontal pyranometer as well as for a tilted pyranometer.
Normal incident radiation of 500 W/m². Spectral content as clear sky solar radiation.

ACCURACY

Unfortunately the sensitivity is cross correlated to a number of parameters as temperature, level of irradiance, vector of incidence, etc. The upper limiting values of the resulting sensitivity variations are listed in the specifications. It classifies the pyranometer CM 21 as a 'secondary standard' according to the classification of the World Meteorological Organization. See table 1.

Table 1 WMO Classification of pyranometers

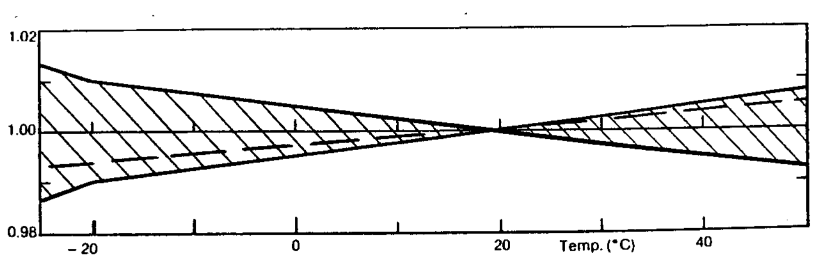
Characteristic	Secondary standard	First class	Second class
Resolution (smallest detectable change in W m^{-2})	± 1	± 5	± 10
Stability (percentage of full scale, change/year)	± 1	± 2	± 5
Cosine response (percentage deviation from ideal at 10° solar elevation on a clear day)	<± 3	<± 7	<± 15
Azimuth response (percentage deviation from the mean at 10° solar elevation on a clear day)	<± 3	<± 5	<± 10
Temperature response (percentage maximum error due to change of ambient temperature within the operating range)	± 1	± 2	± 5
Non-linearity (percentage of full scale)	± 0.5	± 2	± 5
Spectral sensitivity (percentage deviation from mean absorptance 0.3 to 3 μm)	± 2	± 5	± 10
Response time (99% response)	< 25 s	< 1 min	< 4 min

Normally, the supplied sensitivity figure is used to calculate the irradiances. If the conditions differ from calibration conditions, errors in the calculated irradiances must be expected.
For a secondary standard instrument the WMO expects maximum errors in the hourly radiation totals of 3%. In the daily total an error of 2% is expected, because some response variations cancel out each other if the integration period is long.

These errors can be reduced further if the actual sensitivity of the pyranometer is used by the conversion of voltage to irradiance. The actual sensitivity can be calculated when it is a well known function of simply measured parameters (sometimes called transfer function or sensitivity function).

This is especially convenient in connection with a programmable data acquisition system.

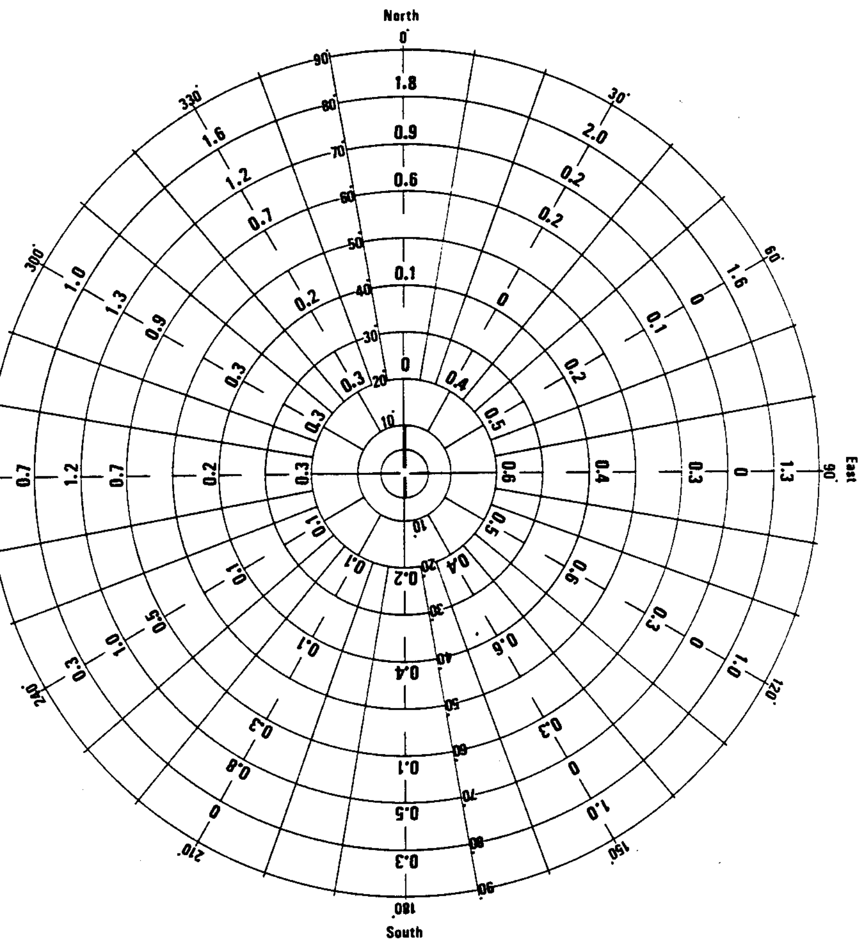
For the CM 21 the effect of each parameter on the sensitivity can be shown separately, because the parameters show less interaction.
The non-linearity error, the sensitivity variation with irradiance, is not measurable for the CM 21 and CM 31.
The temperature dependence of the sensitivity is an individual function. For a given CM 21 the curve is somewhere in the shaded region of fig. 7.



The curve of relative sensitivity variation with instrument temperature of a pyranometer CM 21 is in the shaded region. A typical curve is drawn.

Other effects as directional response, spectral selectivity and zero offset are more difficult to correct for.

The directional response is an individual feature and depends on imperfections of the glass domes and angular reflection properties of the black paint. A polar diagram of combined cosine and azimuth response (= directional response) of the CM 11 810234 is given as an example in fig. 8.
To make corrections on the direct solar radiation with this diagram, the position of the sun on the celestial sphere and the ratio direct/global radiation must be known.
Before leaving the factory, the cosine response of each CM 21 is measured roughly. At a certain zenith angle the 'west' cosine response and 'east' cosine response are determined.
The mean of both values is mentioned on the calibration certificate, expressed as percentage deviation from the ideal proportionality.



8 **Polar diagram of directional response of pyranometer CM 11 810234 expressed as the percentage deviation of the ideal proportionally to the cosine of the zenith angle. The zenith axis was perpendicular to the base of the pyranometer. Orientation: cable was pointing to North.**

Spectral selectivity is the product of spectral absorptance of the black coating (see fig. 9) and spectral transmittance of the glass domes (see fig. 10).
Shifts in the solar spectrum, due to changes from clear to overcast sky, are mainly in the mid of the spectral range. No significant spectral selectivity errors have to be expected. E.g. at a sun's elevation of 30° (airmass 2) only 1% of the solar radiation has wavelengths below 335 nm and only 1% has wavelengths above 2200 mm.

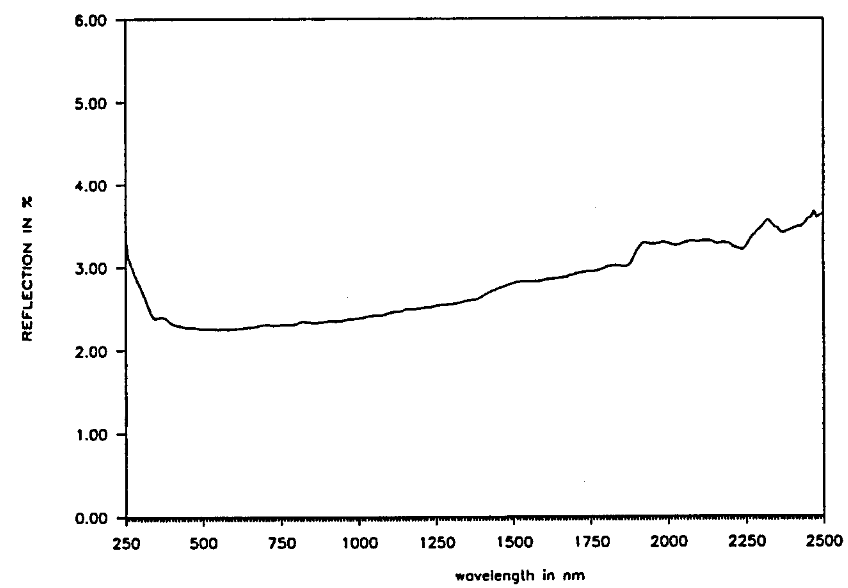
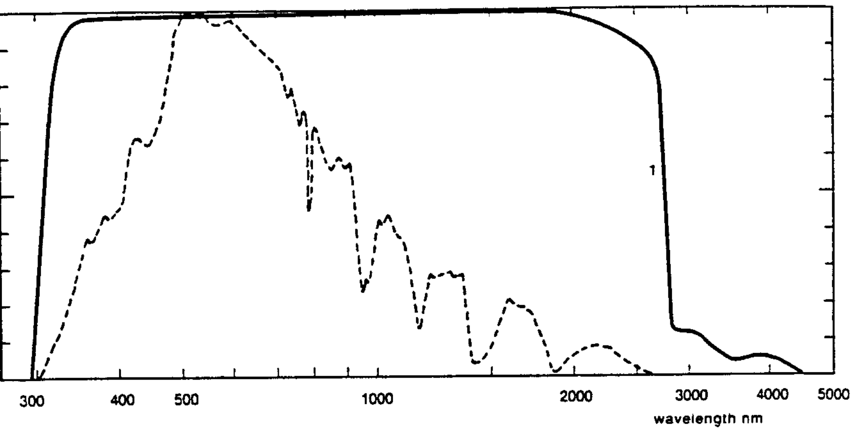


Fig. 9 Spectral reflectance of Carbon black coating as measured in a UV/VIS/NIR spectrophotometer with integrating sphere attachment.



10 1. Relative spectral transmittance of two pyranometer domes.
(Four surface reflections and index change with wavelength are taken into account).
2. Spectral distribution of solar radiation at sea level. Sun at zenith (Airmass 1).

RECALIBRATION

Pyranometer sensitivity changes with time and with exposure to radiation. Deterioration of the black paint may be the reason. Periodic calibration (at least every two years) is advised. Accurate calibrations can be done outdoors under clear conditions by reference to a standard pyrheliometer. Many National Weather Services have calibration facilities. Their standard pyrheliometer is compared with the World Radiometric Reference embodied by several absolute pyrheliometers (black body cavity type),maintained at Davos, Switzerland.

There are several procedures for transferring calibration from a narrow field of view instrument (pyrheliometer) to a wide field of view instrument (pyranometer). E.g. the direct component of the solar radiation is eliminated temporarily from the pyranometer by shading the whole outer dome of the instrument with a disk.
There is another procedure, during which the unknown pyranometer remains in its normal operating condition. This 'component' method involves measuring the direct component with a pyrheliometer and the diffuse component with a disk shaded pyranometer. As during a clear day the diffuse radiance is only about 10% of the global radiation, the sensitivity of the second pyranometer does not need to be known very accurately.
Both procedures are suited to obtain a working standard pyranometer.

Transfer from the working standard pyranometer to other pyranometers can be done in sunlight. The pyranometers must be mounted side by side so that each views the same sky dome. It is desirable to integrate or average the outputs over a period of time and then compute the calibration constants on the basis of these averages. This reduces the errors due to changing parameters during day.

Transfer from another pyranometer in the laboratory is only possible when both pyranometers are of the same type and have the same glass domes and optical coatings. Kipp & Zonen can recalibrate pyranometers according to this method at cost.

Details of calibration methods are found in the WMO guide.
A list of WMO qualified radiation centres which are able to calibrate pyranometers, is copied from the WMO guide in appendix IV.

pendix I

YSICAL PRINCIPLES

e pyranometer CM 21 is provided with a thermal detec-
r. This type of detector responds to the total power
sorbed, and theoretically it is non-selective as to
e spectral distribution of the radiation. This
plies that the naked thermal detector is also
nsitive to longwave infrared radiation (thermal
diation λ > 3000 nm) from the environment.

e radiant energy is absorbed by a black painted disk.
e heat generated flows through a thermal resistance
the heatsink (the pyranometer body). The temperature
fference across the thermal resistance of the
tector is converted into a voltage.

e rise of temperature is easily affected by wind,
n and thermal radiation losses to the environment
cold' sky). Therefore the detector is shielded by two
ass domes. Glass domes allow equal transmitting of
e direct solar component for every position of the
on the celestial sphere. The spectral range of the
ranometer is limited by the transmission of the
ss. See fig. 10. A desiccator in the body prevents
on the inner side of the domes, which can cool down
siderably, at clear windless nights.

struction details (See fig. 11)

n the pyranometer is illuminated, the absorbed
iation results in a heat flow through the sensor to
border of the disk. Natural convection inside the
er dome due to this temperature difference appeared
be small and when tilting a pyranometer CM 21, no
nge of sensitivity is observed.

er heat flows in the sensing element e.g. due to
ng or falling body temperature cause spurious
tage, sometimes called zero offsets. See Appendix
To compensate for one of these offsets, a second
illuminated element is installed, in which the same
flow will arise. By anti-series arrangement of
elements the spurious voltage is cancelled out
tly. The white plastic screen reduces the body
erature variations due to solar radiation and
d) rain showers.

For a given heat flow the sensitivity of the pyranometer is a function of the thermal conductivity of the sensor and of the thermo-electric power of the thermocouple material. These physical quantities show temperature dependency and a thermistor is applied in the electric circuit to keep the sensitivity constant at least for temperatures between - 20° C and + 50° C. See figure 7.

Appendix II

ZERO OFFSET

The following definition of zero offset is used:
When the sensor does not absorb radiation with wavelengths in the spectral range of the instrument and there still is a signal, we call it **zero offset**.
Two types of zero offset are distinguished.

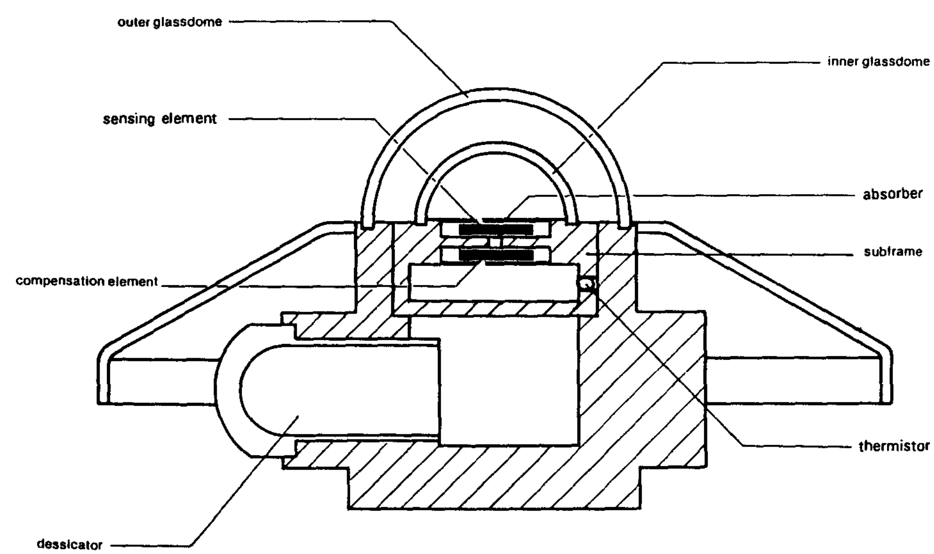


Fig. 11 Approximate construction of Kipp & Zonen pyranometer CM 21/31.

ro offset I

.s zero offset is present when the inner dome has
other temperature than the cold junctions of the
isor. Practically this is always the case when there
a clear sky. Because of the low effective sky tem-
ature (<0° C) the earth surface emits roughly 100
^{2} longwave infrared radiation upwards. The outer
iss dome of a pyranometer also has this radiant
tance and is cooling down several degrees below air
iperature (the emissivity of glass for the particular
relength region is nearly 1). The emitted heat is
racted from the body (by conduction in the dome),
m the air (by wind) and from the inner dome (through
rared radiation). The inner dome is cooling down too
l will attract heat from the body by conduction and
m the sensor by the net infrared radiation again.
latter heat flow is opposite to the heat flow from
orbed solar radiation and causes the well-known zero
ression at night of approx -5 W/m^2. This negative
o offset is also present on a clear day, however,
den in the solar radiation signal.
ing indoor measurements with a solar simulator, the
er dome can become warmer than the pyranometer body
to net thermal radiation from the lamp housing. A
itive zero offset I is the result. The zero offset I
be checked by placing a light tight (paper) box
r the pyranometer. The response to solar radiation
l decay with a time constant of 5 s, but the dome
perature will go to equilibrium with a time constant
several minutes. So after one minute the remaining
nal is the main part of the last zero offset I.

d ventilation of domes *and* body is the solution to
rease zero offset I.

Zero offset II

This zero offset arises when the body (heatsink) temperature increases or decreases. This results in a temperature difference between cold junctions (connected to the heatsink) and the hot junctions due to the heat flow necessary to load or unload the sensor heat capacity. In the CM 21 there is principally no zero offset II because there is a second non-illuminated compensation element. See fig. 11.

SUMMARIZED: Zero offset is the result of lack of thermal equilibrium in the instrument.

Upper values of zero offset in CM 21

Zero offset I: 7 W/m^2 response to 200 W/m^2 thermal radiation (ventilated domes)
Zero offset II: < 2 W/m^2 response to 5° C/hr change of body temperature

Upper values of zero offset in CM 31

Zero offset I: 4 W/m^2 response to 200 W/m^2 thermal radiation (ventilated domes)
Zero offset II: < 2 W/m^2 response to 5° C/hr change of body temperature

The conduction of heat in the quartz domes is greatly improved. This gives better thermal coupling between sensor and top of the domes.
Zero offsets in the CM 31 are therefore significant better than in the CM 21.

endix III

OOR CALIBRATION PROCEDURE AT KIPP & ZONEN, DELFT, LAND

facility

artificial sun is a good quality film sun (Osram) by an AC voltage stabilizer. It embodies a 1000 W gsten-halogen lamp with compact filament. The built- ventilator allows continuous operation. Behind the p is a diffuse reflector with a diameter of 7.5 cm. reflector is 120 cm over the pyranometers, so the arent sundiameter is 3.5°.

minimize stray light from the walls and the opera- , the light is limited to a small cone around the pyranometers. The unknown pyranometer 'a' and the ndard pyranometer 'b' are placed side by side on a ll table. The table can rotate to interchange the itions (1 and 2) of the pyranometers. The lamp is red on the rotating axis of this table. Actually re is no normal incidence of the radiation. But the e of incidence is the same for both pyranometers , so this cannot give rise to errors. The pyrano- ers are not levelled with the screws, but placed on base. The effect of a small tilt is nihil. (Compare 3° = 0.9986 and cos 4° = 0.9976). The irradiance of pyranometers is approx 500 W/m². colour temperature of the light is 3300° K.

procedure

r illuminating during 70 s, the output voltages of pyranometers are integrated during 20 s with a r integrator. Next, both pyranometers are covered n inside blackened 'hat'. After 70 s the zero off- signal of both pyranometers is integrated again. problem of the zero offset is described below. This offset has to be subtracted to obtain the response to illumination. So we get response A and B ectively.
irradiance of position 1 (pyranometer 'a') may be htly different from that of position 2 (pyranometer due to asymmetry in the lamp optics etc. Therefore pyranometers are interchanged and the whole edure is repeated. We get another pair of values: nd B'.

Calculation

The sensitivity of the unknown pyranometer is calculated with the formula

$$S_a = \frac{A + A'}{B + B'} \times S_b$$

S_b is the sensitivity of the standard pyranometer at 20° C.

Zero offset

The lamphouse and diaphragms are emitting longwave infrared radiation, which heats up the outer glass dome and also, indirectly, the inner one. When the pyranometers are shaded off, there still remains a small signal up to + 20 μV due to longwave infrared radiation from the inner dome to the sensor. This zero offset is fading away with a time constant (1/e) of 4 minutes. A zero offset was also embodied in the response readout after illumination. To correct for this unwanted response, the zero offset read after shading is subtracted.

Traceability to World Radiometric Reference

Working standard pyranometers are maintained at Kipp & Zonen. Each standard pyranometer is characterized. Linearity, temperature dependence curve and directional response are well known.

The working standard pyranometers are calibrated each year at the World Radiation Centre in Davos, Switzerland, periodically according to the component method (See also 11).

ppendix IV

ADIOMETRIC LEVELLING

is must be done in the laboratory by mounting the strument on a stand that can be rotated around an is that is accurately vertical and passes through the ntre of the receiving surface. The instrument then is luminated by a lamp so that radiation falls at an evation of e.g. 15° to the horizontal; the lamp should fed by a constant voltage supply.
e output from the radiation instrument is measured at rious azimuths and the level of the instrument ad- sted independently of that of the rotating stand til the least possible variation is obtained as the strument is rotated around the vertical axis. Once is has been done, the spirit level is marked so that e correct level can be found back outdoors.

st of World and Regional Radiation Centres

rld Radiation Centres

Davos (Switzerland)
Leningrad (U.S.S.R.)

gional Radiation Centres

Region I (Africa):	Cairo (Egypt) Khartoum (Sudan) Kinshasa (Zaire) Lagos (Nigeria) Tamanrasset (Algeria) Tunis (Tunisia)
Region II (Asia):	Poona (India) Tokyo (Japan)
Region III (South America):	Buenos Aires (Argentina)
Region IV (North and Central America):	Toronto (Canada) Washington (U.S.A.)
Region V (South West Pacific):	Aspendale
Region VI (Europe):	Bracknell (United Kingdom) Budapest (Hungary) Davos (Switzerland) Leningrad (U.S.S.R.) Norrköping (Sweden) Trappes/Carpentras (France) Uccle (Belgium) MOH Hamburg (Germany)

12. SPARE PARTS

	Part no.
Outer glass dome ϕ 50 mm with metal ring for CM21	0305-162
Outer quartz dome ϕ 50 mm with metal ring for CM31	0305-173
Rubber ring for outer dome of CM 21/31	2132-426
Screen (plastic)	0305-166
lower screen (reflected radiation)	0012-053
Levelling screw (2 required per pyranometer)	0012-117
Fixed foot	0012-116

Complete drying cartridge consisting of:

Clamp-Spring	0305-165
Drying cartridge (without cover)	9012-106
Cover for cartridge	9012-107
Rubber ring	2132-153
Silica gel (1kg) container	2643-943

13. ORDERING INFORMATION

Pyranometer CM 21	1305-975
Pyranometer CM 31	1305-976
Extra cable length	0305-655
Manual pyranometer CM 21/31	0305-205

Recalibration Service

Pyranometers, UV-meters & Pyrgeometers

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 to calibrate their instruments annually.

For instruments that provide an accuracy of >3%	Compare a reference instrument (with an accuracy of better than 1%) with the instrument to be calibrated: ▪For pyranometers and UV-meters, daily totals on sunny days can be compared. ▪For pyrgeometers, nighttime totals can be compared. Deviations of more than 3% for pyranometers (for UV-meters 5%) can be corrected by a new calibration factor.
For instruments that provide an accuracy of <3%	Recalibration is required !

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 being granted.

NAME :
COMPANY/INSTITUTE :
ADDRESS :
POSTCODE + CITY : **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	Confirmation by Kipp & Zonen
		I intend to send the instrument(s) to Kipp & Zonen on: . . . . /. . . . /. . . . I would like to receive the instrument(s) back on : . . . . /. . . . /. . . .	☐ Yes, the dates are acceptable to us. ☐ No, unfortunately the dates do not fit into our calibration schedule. We suggest the following dates: . . . . /. . . . /. . . . (arrival) . . . . /. . . . /. . . . (despatch)

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of recalibration at all times. Please note that special quantity recalibration discounts are being granted.

NAME :
COMPANY/INSTITUTE :
ADDRESS :
POSTCODE + CITY : **COUNTRY** :
PHONE : **FAX** :

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