Kipp & Zonen

INSTRUCTION MANUAL

CUV 3

BROADBAND UV RADIOMETER

0337 302

IMPORTANT USER INFORMATION

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

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

Kipp & Zonen			
Röntgenweg 1	2624 BD	Delft	Holland
P.O.Box 507	2600 AM	Delft	Holland
Phone	+31-15-2698000		
Fax	+31-15-2620351		
Email	info.holland@kippzonen.com		

Kipp & Zonen reserves the right to make changes in the specifications without prior notice.

WARRANTY AND LIABILITY

Kipp & Zonen guarantees that the product delivered has been thoroughly tested to ensure that it meets its published specifications. The warranty included in the conditions of delivery is valid only if the product has been installed and used according to the instructions supplied by Kipp & Zonen.

Kipp & Zonen shall in no event be liable for incidental or consequential damages, including without limitation, lost profits, loss of income, loss of use and other related exposures, however caused, arising from the faulty and incorrect use of the product.

Manual version: 0104

Kipp & Zonen

DECLARATION OF CONFORMITY

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

We **Kipp & Zonen B.V.**
Röntgenweg 1
2624 BD Delft

Declare under our sole responsibility that the product

Type: CUV 3
Name: BROADBAND SCIENTIFIC RADIOMETER

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

Imissions	EN 50082-1	Group standard
Emissions	EN 50081-1 EN 55022	Group standard
Safety standard	IEC 1010-1	

Following the provisions of the directive

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

TABLE OF CONTENTS

1 GENERAL INFORMATION

The UV radiometer type CUV3 is designed to measure broadband global UV irradiance. The instrument has a sensitivity covering the entire UV range, UVA and UVB.

The radiometer is designed for continuous outdoor use in routine monitoring applications with the sun as a source.
It can also be used in indoor applications, bearing the specifications of the source (generally a lamp) and of the radiometer in mind.

A drawing of the radiometer is shown in figure 1.1.

As an output, one obtains a voltage signal that represents the actual UV radiation.
More about electrical connection and about data acquisition can be found in chapters 4 and 5.

Installation, maintenance and operation of the radiometers are relatively straightforward.
These are described in chapters 3 and 6.

The housing of the radiometer is exactly equal to that of the Kipp & Zonen pyranometers. This implies that one can use the same accessories, like the shadow ring and the ventilation unit.

Finally, the calibration of UV radiometers is a subject of controversy in the international scientific community. At Kipp & Zonen one feels that as long as no agreement exists, only a preliminary calibration can be given.
The way, in which calibration is performed, is described in appendix C.

1.1 MEASURING MONOCHROMATIC UV-SOURCES.

The CUV3 radiometer can be used for the monitoring or controlling of different types of UV-lamps, having radiation in the wavelength range of 290 - 400 nm.

On the calibration certificate the maximum sensitivity of the radiometer (at 360 nm) is given. See appendix C.
If monochromatic UV-sources at other wavelength must be monitored, customer should apply the sensitivity figure for that wavelength. This particular sensitivity should be derived from the relative spectral response curve as attached to his calibration certificate.

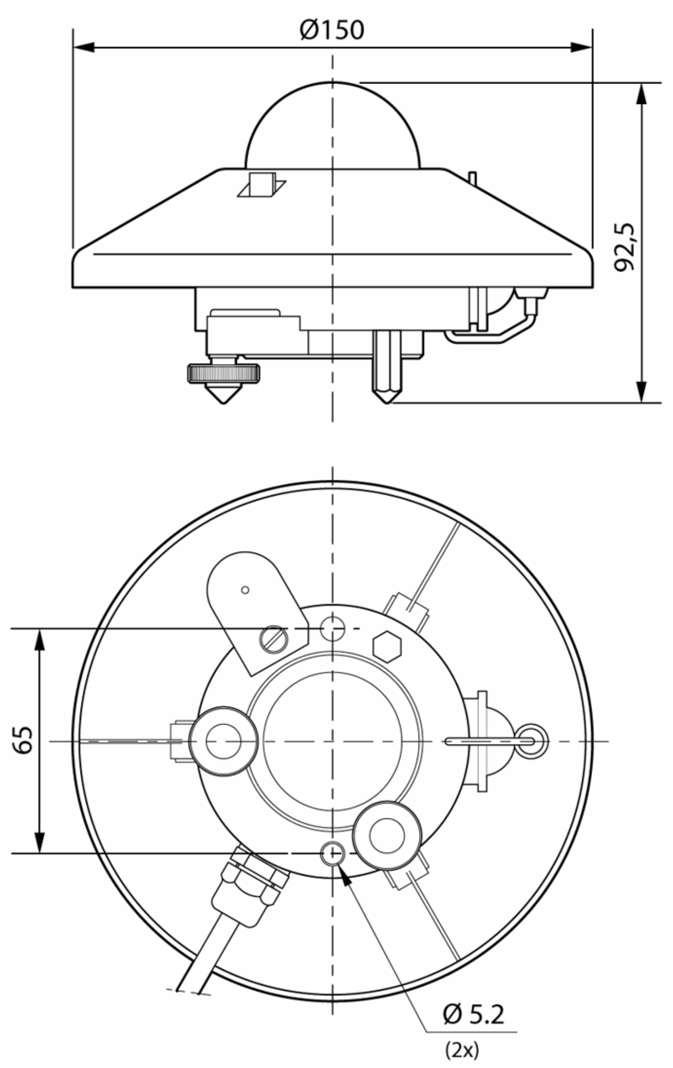


Figure 1.1 Dimensions of the radiometer in mm

1.2 BROAD-BAND UV-RADIATION MEASUREMENTS

The CUV3 radiometer can measure UV-radiation of extended spectra of radiation as from solar radiation and incandescent lamps.

Customer must be aware that: a feature of broadband radiometry is that very different spectra can yield the same integrated irradiances in the bandwidth of the radiometer as long as the spectral response curve of the latter is rectangular (ideal).
The bandwidth of a radiometer with a non-rectangular shape of the spectral response is determined by its half power wavelengths. For the CUV3-radiometer the nominal pass band so becomes 315 - 378 nm. In principle the CUV3 radiometer measures global irradiance within this wavelength interval.

Due to the non-rectangular spectral response curve of the CUV3, it will not weigh UV-radiation of different wavelength equally in this band.
Different spectra with the same irradiance in the CUV3-passband will give different output voltages and consequently each spectra needs its own sensitivity figure (μV/W/m^2).

Feister e.a. (1992) discovered that their broadband UVA sensor (half width 315 - 389 nm) has nearly (within 5 %) the same sensitivity figure for incandescent standard lamps as for air mass 1 and 2 global radiation. The CUV3 radiometer has a second sensitivity figure, which is derived from calibration against a standard lamp. See appendix C. This sensitivity figure should be applied when measuring atmospheric UV-radiation. This figure is also indicated on the indication plate on the housing of the CUV3.

1.3 MEASURING OF EFFECTIVE RADIATION.

This radiation should be measured preferably by "weigthed spectrum" instruments. Their spectral response is in accordance with a specific action curve, for example, the erythemal response of the human skin.

Ångström and Drummond (1962) mentioned a formula to derive effective radiation values from broad-band measurements.

2 SPECIFICATIONS

2.1 OPTICAL

Spectral region	:	290 - 400 nm (nominal)
Nominal half width	:	315 - 378 nm
Side band rejection	:	10^{-6} (400 - 3000 nm)
Cosine error in any azimuth direction (at 10° solar elevation)	:	< ± 10%

2.2 SENSOR SIGNAL

Sensor signal at 365 nm	:	200 - 400 µV/W/m² (nominal)
Signal range	:	0 - 100 mV max.
Operating offset	:	< 10 µV (if input offset current of read out equipment is <1nA)
Temperature dependence of sensitivity	:	< ± 0.1 %/K
Signal range for atmospheric applications	:	0 - 40 mV (nominal)
Non-linearity	:	< 1 % full scale
Tilt response	:	none
Response time	:	< 1 second
Output impedance	:	10 kohm (nominal)

2.3 MISCELLANEOUS

Ambient temperature	:	-40^{o}C to +50^{o}C
Weight sensor	:	1000 g.
Weight sensor plus box	:	1030 g.
Dimensions of packing	:	215 x 180 x 125 mm
Desiccant	:	Silica gel
Materials	:	Anodized aluminum, K5 glass dome
Cable length	:	10 meters

3 INSTALLATION

If possible, a radiometer should be installed such that its field of view is always free from obstructions. In any case, nothing should obstruct the direct radiation from reaching the sensor during any time of the day.
Further, for optimal performance the instrument should not heat up more than strictly necessary. This implies that it should be accessible to convective air and wind, and should in any case not be confined to an insulating surrounding.
Preferably mounting should be done on a plate or a clamp that does not heat up above ambient temperature.
These precautions prevent large errors due to the temperature coefficient of the radiometer.

4 ELECTRICAL CONNECTION

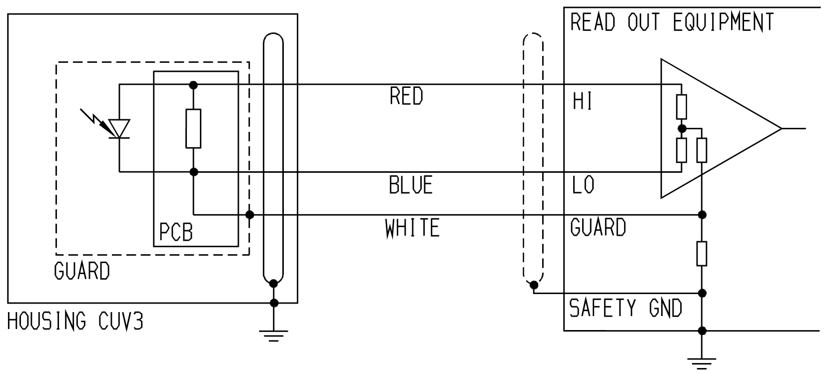


Figure 4.1 Shows a simplified circuit diagram of the radiometer

As an output, one will obtain a voltage signal representing the UV-irradiance in the a plane of the diffuser.

The cable can be extended, as long as the cable impedance is smaller than 0.001 times the acquisition input impedance.
One must be aware of the fact that longer cables enlarge the danger of disturbance by EMF pickup.
Please connect the shielding to your systems ground.

5 AMPLIFICATION AND DATA ACQUISITION

The output range can be found in the specifications. In case that a lamp is used as a source, one will need to estimate the range oneself, multiplying the lamp spectrum and the radiometer spectral sensitivity. The sensitivity of the radiometer at 360 nanometer is specified. The manufacturer can give the irradiance and spectral properties of the lamp.
It is advised to use a data acquisition system with a voltage input and an input impedance that is larger than 10 Mohm. This will add a negligible load to the relative high impedance radiometer.

Although it generally will not be significant, it is suggested to monitor the nighttime offset, and to subtract this value from the daytime values.
This offset might be caused by the sensor or by the data acquisition system.
Check input offset current of the latter because this current can produce many micro volts offset across the input impedance of the CUV3.

As atmospherical phenomena do not change very rapidly, it will generally be sufficient to work with sampling times that are of the order of magnitude of 1 second.

The CUV 3 radiometer can also be used in combination with the Kipp & Zonen SOLRAD Integrator.
The SOLRAD is a hand-held datalogger for direct irradiance read-out. It is also capable of storing up to 31 integration values into it’s internal memory, which is enough to cover the daily values for a whole month.

6 MAINTENANCE AND OPERATION

Once installed, the radiometer will need little maintenance.

As part of the weekly routine, cleaning of the domes is suggested.

As part of a monthly routine, cables and leveling could be inspected.

On a yearly basis, a check of the calibration is advised. This can either be done by letting a reference instrument run parallel, or by performing an indoor calibration at either Kipp & Zonen or at a local calibration facility.
As indicated in chapter 1, calibration still is an object of controversy. Consequently calibration values that are obtained from different institutes will probably differ.

7 DELIVERY AND SPARE PARTS

7.1 DELIVERY

The radiometer is delivered as follows:

Radiometer	1337904
Manual	0337302
Calibration certificate	

7.2 OPTIONS

If the radiometer is ordered with a specially requested spectral response, this will be indicated on the calibration certificate.

7.3 SPARE PARTS

The following spare parts are available:

Drying cartridge for CUV3 0305721
(Including cartridge, cover, rubber ring and clamp spring)

Glass dome on mounting ring 0305162

White sun shield 9012192

Levelling screw 0015603
(2 are required per instrument)

Fixed foot 0015604
(1 is required per instrument)

Additionally, one can obtain spare filters. Preferably these are exchanged at Kipp & Zonen, because both the calibration factor and the spectral response will be affected.

APPENDIX A OPTIONS

A1 SHADOWRING CM121

As an option for using with global UV radiometers one can use a shadowband CM 121. The band will shield the sensor from direct radiation. As a result only diffuse radiation will be measured. The shadowband will however also occult part of the diffuse sky. Correction figures are available, valid for an isotropic sky.
The diffuse UV-radiation is of the same order of magnitude as the direct UV-radiation, because the Raleigh scattering (at molecules) is approx 50%.

One should realize that the spectral distribution of the diffuse UV-radiation is slightly different from the spectral distribution of the total (sky and sun) radiation (WCRP manual).

For further information we refer to the manual of the shadowring.

A2 VENTILATION SYSTEM CV 2

As an option to the global UV radiometers, the ventilation system CV 2 can be used.
The ventilation system will blow air around the body and over the dome of the radiometer.

Under conditions of clear windless nights, when dew is bound to be deposited on the radiometer domes, ventilation will prevent dew deposition.

Ventilation will also prevent snow-buildup (although it will not be effective against heavy wet snow).

For further information we refer to the manual of the ventilation system.

A3 ALTERNATIVE SPECTRAL SPECIFICATIONS

The design of the UV radiometers is quite flexible; by exchanging filters and possibly photodiodes for alternative ones, the spectral specifications can be adapted to required specifications.

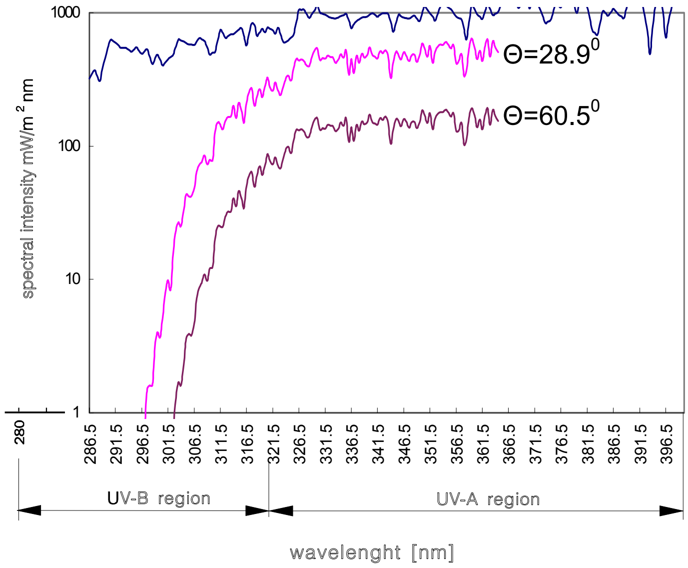
Offers for radiometers with alternative spectral specifications can be given on request.

APPENDIX B PHYSICAL PRINCIPLES

B1 ATMOSPHERIC UV RADIATION

Ultraviolet radiation has many, mostly harmful, effects on man and the environment.
The negative health effects of UV exposure are: e.g. skin cancer, skin ageing, Erythema (tanning, sunburn), cataracts, keratitis and most probably immuno depression.

The sun is the primary source of UV exposure and especially the shorter UV-B wavelength (280 - 320 nm) are most effective in inducing the aforementioned effects.
Because solar UV-B radiation is very strongly absorbed by ozone in the atmosphere, it is mainly the composition of the latter which determines the amount of UV-B reaching the earth surface.
This is illustrated with figure B.1.



B.1 Spectrum of direct! UV-radiation above the atmosphere and of global UV-radiation for two Sun's zenith angle (Θ=28.9° and Θ=60.5°)
Conditions: clear sky, sea level, 14 June 1994,
De Bilt The Netherlands

Above the atmosphere the (extraterrestrial) UV-B and UV-A radiation changes not much with wavelength and ranges from approx. 0.5 to 1.5 W/m^{2}nm direct spectral irradiance at 300 resp. 390 nm.
Caused by the increasing spectral absorptivity of ozone for wavelength below 320 nm (Huggins bands) the UV-B global irradiance at sea-level drops down at shorter wavelength very rapidly.
The decrease of direct UV-A irradiance with wavelengths above 340 nm is mainly caused by Rayleigh scattering on aerosols and molecules.
With sun in zenith the scattering for radiation with wavelength of 400 nm is 30 %. At sun's elevation 10^0 the scattering is 88 %.

For 300 nm wavelength this figures are 71% and 100%!

Part of the scattered UV-radiation is reaches the ground as diffuse radiation. Half of the 306 nm UV-B irradiance is diffuse!
This diffuse radiation is polarized dependent on the scattering angle.
The fine structure of the sea-level spectra is partly of extraterrestrial origin but there are also absorption dips of sulphur dioxide (at 306 nm) and other gasses.

Broadband UV radiometers like the Kipp & Zonen CUV3 have band pass filters with bandwidth of 30 nm or more.
They are excellent for monitoring UV-output of different lamps.
Measuring of atmospheric UV-radiation with the CUV3 is possible, but it is important to realize that it does not give the relevant information of harmful UV-radiation; the longer wavelengths dominate the signal.

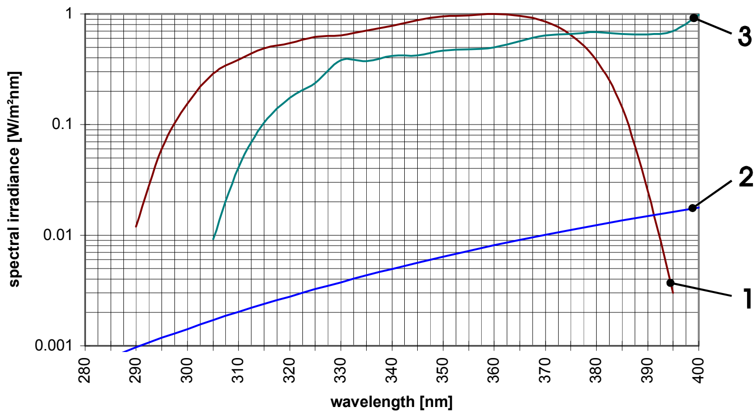
B2 SENSOR PROPERTIES & INUCCURACY

B.2.0 GENERAL INFORMATION

Generally, inaccuracy in radiometers reveals itself if several radiometers of different manufacturer are placed side by side under the same irradiance. Also radiometers of the same type and manufacturer exhibit discrepancies because some properties differ per individual radiometer, like cosine/azimuth response, temperature coefficient of sensitivity. Bandwidth and possibly an individual blocking for the remaining solar radiation.

B.2.1 SPECTRAL RESPONSE OF CUV3 RADIOMETER

The accuracy of the CUV3 radiometers is mainly determined by the properties of the band pass filter. Fig.B.2 shows spectral response of CUV3 on a logarithmic scale. A linear plot of the CUV 3's relative spectral response attached to the calibration certificate.
Solar noise for 1000 W/m^2 solar radiation with λ>408 nm is smaller than 2 µV (>0.01 W/m^2).



1 CUV 3 relative spectral response (relative units).
2 Spectrum of standard lamp of spectral irradiance.
3 Hemispherical solar radiation for AIRMASS 1.5 (sun's zenith angle=37°)

B.2 Typical relative spectral response of CUV3 to monochromatic light (1) and two UV spectra (2,3).

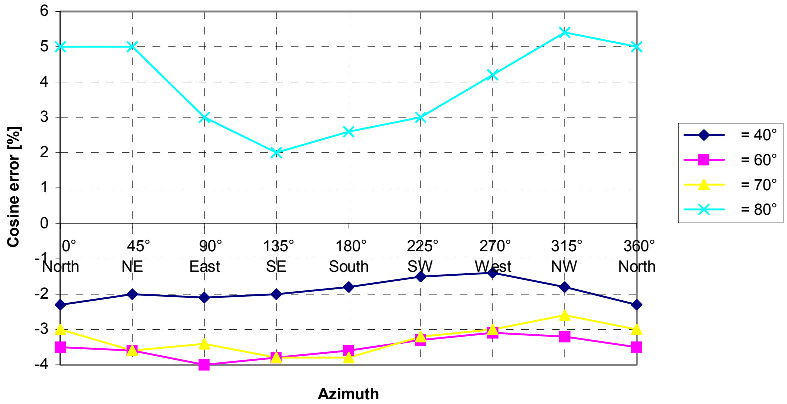
B.2.2 DIRECTIONAL SENSOR PROPERTIES

By definition global radiation G is the downward irradiance, both direct and diffuse, on a horizontal surface. In other words, G represents the downward vertical component of the radiation field. Especially the accurate measurement of the vertical component of the direct radiation I.cos Θ requires a detector with a so-called cosine response (Θ is the sun's zenith angle). In pyranometers with thermal detectors a good cosine response is reached with flat black absorber paint and proper domes.
For measurement of weak UV-signals in small wavelength - intervals photo-electric detectors are more attractive.
However photodiodes and the interference filter needed cannot accept radiation with large incidence angles Θ.
A diffuser is necessary which accepts radiation from at least a full angle of 170E.
The dimensions of the diffuser ensure a good cosine response but due to tolerances in diffuser and protecting dome each UV-radiometer has its own individual directional response.
To ensure that the response at 90E incidence angle is zero (cos. 90E= 0) a shadow of a rim shades off the diffuser side for angles >85E.

Cosine errors for a typical CUV3 radiometer are shown in figure B.5. The cosine error in the direct radiation for different incidence angles is displayed as a function of the azimuth direction.
For example: in the diagram a cosine error of -3.6 % is read off for azimuth direction South and sun's zenith angle 60E.
This means that the response to the direct radiation is 3.6 % too low. However especially in the UV region half of the response is due to diffuse radiation so the effect of the cosine error is reduced at least a factor 2. For your information we mention some scattering values. Of the extraterrestrial direct UV-radiation impinging with zenith angle 0E respectively 80E is scattered:
For wavelength 400 nm: 30% resp. 88%
For wavelength 300 nm: 70% resp. 100%
So especially at 80E sun's zenith angle there is hardly direct UV-B radiation.

It is not necessary to correct for the cosine error. The diagram is only

given as qualitative information. The diffuse radiation undergoes the same cosine errors but of course "weighted" over all zenith and azimuth angles. From some parts of the sky strongly polarized diffuse radiation is received.
However the diffuser depolarizes this radiation.



B.2.2 Cosine error versus azimuth of CUV3 REF 1 at different sun's zenith (cable pointing North)

APPENDIX C CALIBRATION

In the calibration certificate of a CUV3 radiometer two sensitivity figures are mentioned.

The first sensitivity figure gives the response to monochromatic UV-radiation with 360 nm wavelength in µV per W/m^2 of homogeneous irradiance at the plane of the diffuser surface.
This sensitivity figure is determined at Kipp & Zonen Delft BV by comparing to a reference standard CUV3 in a filtered (CWL/BW 360/10nm) parallel Xenon lamp beam.
The reference standard is calibrated at the Department of Physical Standards of the Nederlands Meetinstituut, Van Swinden Laboratory, Delft, The Netherlands. There the Kipp standard CUV3 was compared in monochromatic light (365 nm, bandwidth < 5 nm) to a silicon Photo diode, which on his turn was calibrated at the National Research Council of Canada. The basis of the absolute spectral responsivity scale at the NRC is a group of four electrical-substitution absolute radiometers.

The second sensitivity figure must be applied when measuring radiation of sources which spectra extend the bandwidth of the CUV3 radiometer.
This sensitivity figure should give the response per W/m5 of radiation within the nominal bandwidth (315 - 378 nm) of the CUV3. Because the spectral response curve is not ideal (rectangular), the sensitivity figure is only exact for one typical spectral distribution, that is a spectrum of an incandescent lamp.
This sensitivity figure of the CUV3 is determined at Kipp & Zonen Delft BV by comparing against a reference standard CUV3 in a vertical cone of light (approx. 500 W/m^2) from a tungsten-halogen lamp as described in ISO 9847 Annex A.3.1 . The UV irradiance in the pass band of the CUV3 was approx. 1.4 W/m^2.

The reference standard itself is calibrated at the Royal Netherlands Meteorological Institute, De Bilt, Holland in front of a standard lamp, type: Standard of Spectral Irradiance OL FEL-C.
The spectral irradiance from this lamp integrated from 315 nm to 378 nm yields an irradiance of 0.406 W/m^2.

C1 RECALIBRATION SERVICE

Pyranometers, UV-meters, Pyrgeometers &
Sunshine duration sensors

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 have attached three fax forms to schedule the recalibration of your instrument(s) at Kipp & Zonen.

NAME :
COMPANY/INSTITUTE :
ADDRESS :
POSTCODE +CITY :
COUNTRY :
PHONE :
FAX :
E-MAIL :

☐ **I would like to receive a price estimate for recalibration**

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

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

Conformation by Kipp & Zonen
☐ Yes, the dates are acceptable to us ☐ No, unfortunately the dates do not fit into our calibration schedule. We suggest the following dates: . . . . . ./. . . . . ./. . . . ./. . . . . ./. . . . . .

Fax +31-15-262-0351

or mail to:

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

NAME :
COMPANY/INSTITUTE :
ADDRESS :
POSTCODE +CITY :
COUNTRY :
PHONE :
FAX :
E-MAIL :

☐ **I would like to receive a price estimate for recalibration**

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☐ Yes, the dates are acceptable to us ☐ No, unfortunately the dates do not fit into our calibration schedule. We suggest the following dates: . . . . . ./. . . . . ./. . . . ./. . . . . ./. . . . . .

Fax +31-15-262-0351

or mail to:

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

APPENDIX D CIRCUIT DESCRIPTION

The UV-sensor is a GaP Photodiode connected in the photovoltaic mode (zero bias operation), which sources current ID proportional to the incident UV-radiation power on its active surface. This photon induced current, or photocurrent, will divide between the diode internal junction resistance (RSHUNT) and the parallel load resistance. The direction of photocurrent flow in the extended circuit will produce a voltage across the load resistor that will act as a forward bias on the p-n junction. It is this external voltage source, created by the combination of radiation power, junction resistance, and load resistance that defines and limits the performance of a photovoltaic p-n junction as a linear radiation detector. At very low values of load resistance the voltage develops across the load resistor. Even at high values of irradiance this is insignificant and fails to produce any detrimental effects in the device's performance. This operating mode is referred to as the short circuit operating mode.

The dynamic impedance of the photovoltaic p-n junction is defined by the slope of the dark I/V characteristic as it passes through zero Volts. Because this impedance shunts the load resistance and photocurrent source in the electrical equivalent circuit (shown in figure x) it is commonly referred to as the shunt resistance.

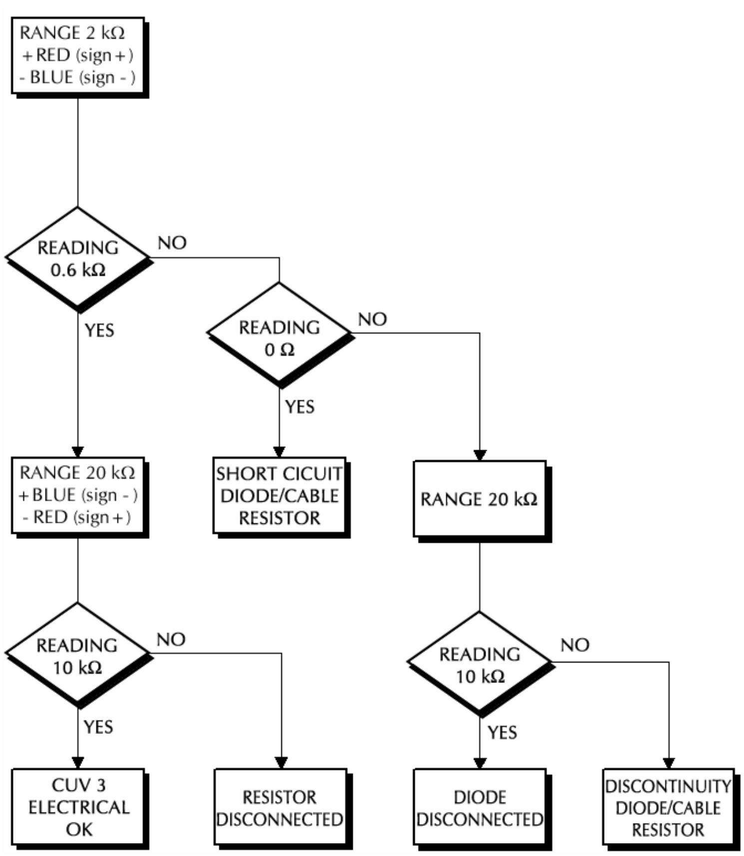
The shunt resistance is not only active area dependent, it is also temperature dependent.

As can be seen from figure x there are two other elements that need attention. The junction capacity CD is active area dependent and plays a role in the stability and noise analysis of the combination amplifier/photodiode.

The series resistance is the sum of contact resistance and bulk silicon resistance. The latter is inversely proportional to the active area. The series resistance of lower area photodiodes can usually be neglected.

APPENDIX E TROUBLE SHOOTING

In case of malfunction of the CUV3, a simple check can be done, in order to localize a possible fault in the electrical circuit.
Connect a digital multimeter (e.g. Fluke 8010A)
Connections and ranging as below:



E.1 Trouble shooting flow chart

APPENDIX F LITERATURE

Ångström A.K., Drummond A.J.	Fundamental principles and methods for the calibration of radiometers for photometric use. Appl. Opt. 1(4), 1962.
Feister U., Grasnick K.H., Grewe R.	Instruments for broad-band UV radiation measurements. Solar Energy Vol.49, No.6,1992.
Fröhlich C. and London J.	Revised instruction manual on radiation instruments and measurements. WMO/TD-No. 149. World Meteorological Organization, Geneva, Switzerland, 1986.

Customer Support

Our customer support remains at your disposal for any maintenance or repair, calibration, supplies and spares. The address is as follows:

Für Servicearbeiten und Kalibrierung, Verbrauchs-material und Ersatzteile steht Ihnen unsere Customer Support Abteilung unter folgender Adresse 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. Leur adresse est la suivante :

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