KIPP & ZONEN
SINCE 1830

UVS series

UV Radiometers

Instruction Manual

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 pleased to receive them at:

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Kipp & Zonen reserve the right to make changes to 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 business opportunities, loss of use and other related exposures, however caused, arising from the faulty and incorrect use of the product.
User made modifications can affect the validity of the CE declaration.

Manual version: 0712

CE

DECLARATION OF CONFORMITY

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

We **Kipp & Zonen B.V.**
Of **Delftechpark 36**
2628 XH Delft
The Netherlands

Declare under our sole responsibility that the products

Types: **UVS-A-T, UVS-B-T, UVS-E-T, UVS-AB-T, UVS-AE-T**
Name: **UV 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

1.1 INTRODUCTION

The radiometers of the UVS Series (UVS-A-T, UVS-B-T, UVS-E-T, UV-S-AB-T and UVS-AE-T) are designed for precise measurements of atmospheric ultraviolet radiation in three different spectral ranges. All models measure global UV radiation, i.e. the sum of direct solar radiation and the radiation which has been scattered by particles or molecules in the air. The angular response follows the cosine of the zenith angle as with an ideal Lambertian surface.

The internal filter optics, detector and electronic preamplifier of the UVS Series are thermo-electrically controlled at a temperature of +25°C, independent of the external temperature. This eliminates variations of the spectral sensitivity caused by changing ambient temperatures. In order to allow monitoring of the internal temperature, an analog voltage output is available, generated by an independent control circuit.

The spectral sensitivity of the UVS-E-T corresponds to that of the human skin with regard to the Erythemal Action Spectrum ISO 17166:1999 / CIE S 007/E-1998. This is the response required by the United Nations, World Health Organisation and World Meteorological Organisation for measurement of radiation according to the Global Solar UV Index (UVI). The analog output voltage is a direct measure of the erythemally active UV irradiance in W/m^2. This irradiance can also be expressed in UV Index by multiplying with the constant 40 m^2/W.

The UVS-A-T and UVS-B-T radiometers allow precise measurements of atmospheric UV-A and UV-B irradiance. The analog output voltage is proportional to the irradiances in W/m^2.

The dual band radiometers UVS-AB-T and UVS-AE-T have two separate outputs, one for the UV-A band irradiance and one for UV-B band irradiance (UV-S-AB-T), or one for UV-A and one for the Erythemally Active UV irradiance (UVS-AE-T). The spectral and angular characteristics correspond to those of the respective single band radiometers.

2 TECHNICAL DATA

	UVS-A-T	UVS-B-T	UVS-E-T	UVS-AB/AE-T
Optical				
Type	Single band			Dual band
UV irradiance measured	UV-A	UV-B	Erythemally Active UV-E	UV-A + UV-B UV-A + UV-E
Nominal spectral response	315-400 nm	280-315 nm	ISO 17166:1999 / CIE S 007/E-1998	See individual radiometers
Response at > 400 nm	< 0.1% of output			
Cosine response	< 2.5% between 0°and 70° solar zenith angle			
Electrical				
Nominal output 0 - 3 Volt	0 – 90 W/m^2	0 – 6 W/m^2	0 – 0.6 W/m^2	See individual radiometers
Output of internal temperature	2.5 V ~ 25 °C (see Appendix II)			
Operating temperature	- 25 °C to + 50 °C, full specification - 40 °C to + 50 °C, reduced specification			
Power supply	7-18 VDC, 8 W			
Mechanical				
Materials	Housing: protected aluminium, polyester coated Dome: UV-grade quartz			
Connector	Binder 712 Series, 8 pole			
Height Diameter	145 mm 122 mm			
Weight	< 1 kg			

3 INSTALLATION

When installing the radiometer you must consider:

1. The radiometer should be installed as high as possible to minimize obscuration by trees, buildings, etc. This includes the obscuration of the indirect, scattered radiation coming from the whole upper hemisphere. A large portion of the received UV radiation does not reach the radiometer directly from the sun, but is scattered by molecules and particles. Ideally the view should be clear to the horizon in all directions.

2. The radiometer should be carefully levelled in the horizontal plane. Use the built-in spirit level to find the correct position.

3. The installation of the radiometer must ensure natural ventilation to reduce heating of the housing caused by solar radiation and electrical power dissipation. If the housing becomes too hot, damage may occur.

3.1 PIN CONNECTIONS OF ALL UV VERSIONS

Pin connection scheme of the connector
[color of wire in yellow connection cable]:

1 -	V+: [red]	positive supply for signal circuit, 7 - 18 V, 1 W
2 -	HEAT-GND: [blue]	heater ground
3 -	UV-X-OUT: [green]	UV-B or UV-E output, 0 - 3 V not connected in UVS-A-T
4 -	TEMP-OUT: [yellow]	internal temperature output see table in Appendix II
5 -	GNDA: [grey]	ground for signal outputs
6 -	HEAT V+: [brown]	positive supply voltage for heater 7 - 18 V, 8 W
7 -	UV-A-OUT: [white]	UV-A output, 0 – 3 V not connected in UVS-B-T or -E-T
8 -	GNDA: [black]	ground for signal circuit

Voltage drop over connection wires:

For correct operation of the sensor it is required that the power supply and the connection cable have a total resistance which does not exceed a critical value $R_{max.}$ This is to prevent voltage drop over the connection wires that will reduce the supply voltage beyond the lower operating limit of the radiometer electronics.

The formula for R_{max} is:

$$R_{max} = ([VT+] - 6\ V) / 1.2\ A$$

where [VT+] is the supply voltage and R_{max} is the sum of the total wire resistance and the internal resistance of the power supply.

Example 1:
The supply voltage is 12 VDC. The internal resistance of the power supply is 1 Ω (i.e. voltage drop of 1 V at 1 A load). Then the allowable total wire resistance (sum of positive and negative supply wire) is 4 Ω.

Example 2:
To calculate the minimum voltage that is required for correct operation of the radiometer with the standard cable of 10 m length, the above equation has to be reformulated as follows:

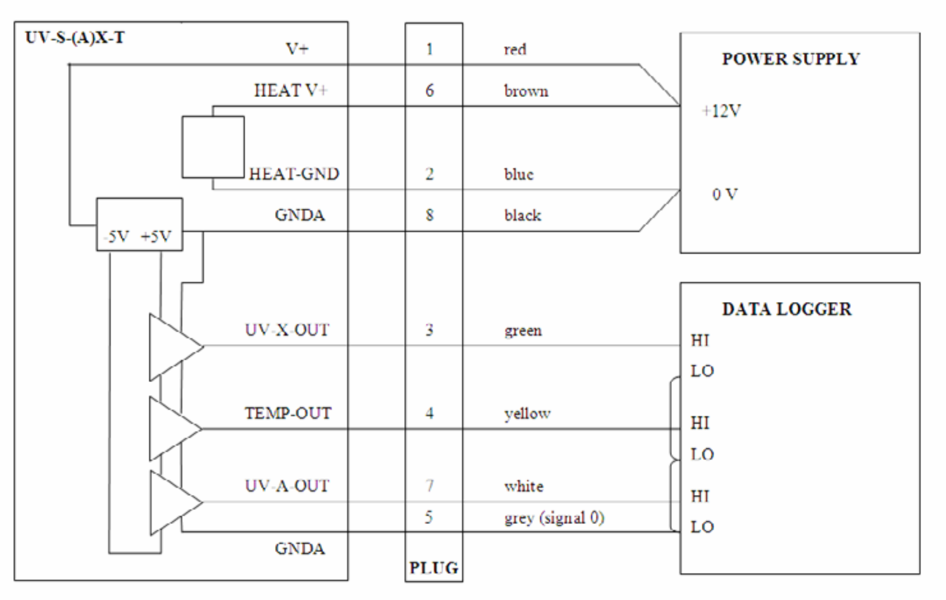
$$[VT+] = 1.2A \bullet R_{tot} + 6V$$

where R_{tot} is the sum of the resistances (internal resistance of the power supply and total wire resistance). With the wire resistance of 0.15Ω/m a total wire resistance of 2 x 1.5Ω = 3Ω for the standard 10 m cable is obtained. With an internal resistance of 1Ω (power supply) the sum of the resistances is 4Ω (equals R_{tot}). To compensate for the voltage drop over the wires and power supply, the voltage supply [VT+] must be at least 10.8V. Hence, with a power supply (internal resistance 1Ω) that provides at least 10.8V the radiometer will operate correctly.

Data logger input channels:

To prevent earth loops that influence the quality of the data from the radiometer it is recommended to use floating inputs to measure the output voltage signals. If the input of the data logger is not floating it may be useful to test the radiometer signal for noise due to earth loops over the data logger input channels.

Connection scheme: UV series



Important notes:

- Pin 3 (green wire) is the UV-B or UV-E output.
- For single band UV-B or UV-E instruments, pin 7 (white wire) is not connected.
- The analog ground pin 5 (grey wire) should **not** be grounded. This can cause ground loops and offsets, especially when the 0 Volt of the power supply is grounded.

4 CALIBRATION AND UVIATOR SOFTWARE

From late 2007 the specially developed Kipp & Zonen UVIATOR Software is included with all new UVS radiometers. The use of the UVIATOR is explained in the UVIATOR manual. In this chapter the benefits and the principles are explained.

Why use UVIATOR software

To improve the quality and relevance of measured UV irradiance data from UVS radiometers by taking into account the spectral properties of the radiometer and of the atmosphere at the time and location of the measurement.

Theoretical Background

Atmospheric ultraviolet radiation measurements are difficult to perform due to the drastic decrease of UV-B irradiance towards shorter wavelengths, caused by the strong stratospheric Ozone absorption. Besides the extinction of UV radiation due to Ozone, Rayleigh scattering also affects the radiation, especially in the UV-B spectral region.

As UV radiation represents only a small portion of the solar spectrum, broad-band UV radiometers contain filters and use signal amplifiers to measure the UV irradiance in the appropriate spectral region. Filters are used to measure the UV irradiance in the UV-A or UV-B spectral region, or to match as closely as possible a specific theoretical weighting function, such as UV-E.

As the actual radiometer spectral response functions do not correspond exactly to the theoretical weighting functions, even for the radiometers measuring only UV-A or UV-B irradiances, the measurements are affected by a systematic error caused by spectral mismatch.

The UVS Series is suitable for the measurement of UV irradiance according to theoretically defined UV-A, B and E spectra. In general all broad-band filter instruments have limited performance due to the intrinsic spectral mismatch of each sensor with respect to the theoretical definitions of UV-A, B and E.

By knowing the spectral mismatch in detail, one can compensate the instrument effects for different measurement conditions. Kipp & Zonen has developed a unique software program for post-processing and analysis of UVS data. The UVIATOR program performs automatically a number of UV measurement corrections and thereby improves the measurement quality significantly.

The spectral mismatch error correction is based on the correction method described in the WMO Report No. 141 [Ref. 2]. Further explanations and discussions of the spectral mismatch error are presented in a number of publications listed at the end of this section.

4.1 UV RADIOMETER CALIBRATION AND CORRECTION METHOD

To achieve the most accurate measurement result with broad-band UV radiometers, the raw signals must be transformed into UV irradiances using two "Calibration Steps" (A and B), and an "Adjustment Step".

Calibration Step A:
The raw signal of the instrument (in units of Volts) has to be transformed into an irradiance (in units of W/m2). To achieve this transformation a so-called "radiometric calibration factor", denoted as ρ (in units of V/W/m2), has to be determined.

Calibration Step B:
The irradiances have to be corrected for the spectral mismatch error with “conversion factors”, denoted as γ (no units). These conversion factors are determined using modelled UV irradiances as a function of various total Ozone column densities and solar zenith angles.

Adjustment Step:
The corrected UV measurements are obtained by multiplying the raw UV radiometer reading under outdoor measurement conditions with an appropriate “adjustment factor”, χ, defined as $1/(\rho \bullet \gamma)$. The appropriate adjustment factor has to be chosen according to the measurement conditions at the time of the UV radiometer reading.

The Adjustment Step which provides the final, corrected, UV irradiance (in units of W/m2) is carried out by the UVIATOR program for each individual UVS radiometer reading. Before the broad-band UVS radiometer can be used in the field, it must be factory calibrated according to Calibration Steps A and B, which provide the calibration and correction factors for a particular instrument.

The next two paragraphs describe Calibration Steps A and B as they are performed at Kipp & Zonen. The final paragraph of this chapter describes the Adjustment Step as implemented in the UVIATOR program.

4.1.1 CALIBRATION STEP A: DETERMINATION OF THE RADIOMETRIC CALIBRATION FACTOR

The radiometric calibration of the broad-band UVS radiometers is performed with a Xenon lamp, a monochromator and a calibrated Silicon photo-diode detector. The photo-diode and the test UVS radiometer are mounted behind the exit slit of the monochromator.

They are exposed to spectral irradiances between 280nm and 400nm (step increments 1 nm, slit width 2 nm at FWHM). The spectral measurements are performed sequentially as the monochromator has one exit slit only. Nevertheless, identical monochromator output signals can be achieved for the photo-diode and the UVS radiometer by positioning the sensitive surfaces of both detectors at the same distance from the exit slit.

A calibration factor is defined as the ratio between the radiometer output and the radiation input, i.e. the radiometer reading divided by the UV irradiance. To obtain the radiometric calibration factor, ρ, in the laboratory, the UV radiometer output and the UV irradiance input are determined using the monochromatic measurements.

The broad-band UV radiometer output can be calculated according to:

$$U_{UVS} = \int u_{UVS}(\lambda) \bullet d\lambda$$

where $u_{UVS}(\lambda)$ are the spectrally measured test UVS readings. $u_{UVS}(\lambda)$ is also referred to as the spectral response function. The index *UVS* denotes the variable of a broad-band UVS radiometer. The radiometer-weighted UV irradiance input, can be calculated as:

$$E_{UVS} = \frac{\int e_{Si}(\lambda) \bullet s_{UVS}(\lambda) \bullet d\lambda}{A_{eff}}$$

where $e_{Si}(\lambda)$ is the irradiance (in units of W/nm) of the monochromator output (measured with the photo-diode), $s_{UVS}(\lambda)$ is the normalized spectral response function of the test UVS radiometer (i.e. $u_{UVS}(\lambda)/\max(u_{UVS}(\lambda))$), and A_{eff} is the effective area (in m^2) of the UVS radiometer detection surface. Finally, the radiometric calibration factor is obtained from the two monochromator-based measurements (U_{UVS} and E_{UVS}) according to $\rho=U_{UVS}/E_{UVS}$. The units of ρ are V/(W/m2).

4.1.2 CALIBRATION STEP B: DETERMINATION OF THE CONVERSION FACTOR TABLE

Without any measurement correction, a broad-band UV radiometer can provide results that deviate by a factor of 2 or more from the true values. The magnitude of the deviation depends mainly on the extent of the spectral mismatch and the measurement conditions.

The measurement conditions for which correction factors are calculated are obtained by varying the solar zenith angle, Θ_0, and the total Ozone column density, $[O_3]$ in the radiative transfer model TUV [Ref. 3]. Other atmospheric parameters affecting UV irradiances, such as extinction due to aerosols, are not explicitly included as they are assumed to be comparatively small.

The modelled UV spectra are used to determine the conversion factors, $\gamma\,(\Theta_0, O_3)$, which are defined as:

$$\gamma = T_{UVS}/T_{UVX}$$

where T_{UVS} and T_{UVX} denote the normalized spectral response function-weighted irradiance and the 'true' irradiance, respectively:

$$T_{UVS}(\Theta_0, O_3) = \int e_{TUV}(\lambda, \Theta_0, O_3)\, s_{UVS}(\lambda)\, d\lambda$$

and

$$T_{UVX}(\Theta_0, O_3) = \int e_{TUV}(\lambda, \Theta_0, O_3)\, s_{UVX}(\lambda)\, d\lambda$$

where $e_{TUV}(\lambda, \Theta_0, O_3)$ denotes the TUV modelled irradiance as a function of the variable input parameters Θ_0 and O_3. Note, that the 'true' irradiance, T_{UVX}, represents the modelled irradiance weighted with a theoretical spectral response function, $s_{UVX}(\lambda)$. Such a theoretical spectral response function could be the Erythemal weighting function CIE-1987 [Ref. 4]. The conversion factors calculated with the Erythemal weighting function provide the corrections for the UVS-E-T and UVS-AE-T radiometers.

The solar zenith angles, Θ_0, are varied between 0° and 85° (using steps of 5°) and the Ozone column densities, [O_3] are varied between 200 Dobson Units (DU) and 500 DU (using steps of 10 DU), yielding 18 x 31 = 558 conversion factors. If UV irradiances have to be measured with broad-band UV radiometer under exceptional conditions, it is recommended to calculate new conversion factors using model parameters that are representative for the exceptional condition (e.g. snow-covered land surface at a location which is mostly snow -free).

4.2 ADJUSTMENT STEP: UVIATOR CORRECTION METHOD

To obtain the most accurate UV irradiances using broad band UV radiometers, the readings ("raw radiometer output") must be multiplied with the adjustment factor, χ. This is a combined correction factor, composed of the radiometric calibration factor, ρ, and the conversion factor, γ, i.e. $\chi=1/(\rho\bullet\gamma)$.

The UVIATOR program performs the required selection of the appropriate conversion factor automatically and corrects an instantaneous UVS measurement according to the conditions at the time and location of the measurement. For the selection of the conversion factor, the parameters Θ_0 and O_3 have to be determined according to the measurement conditions at the time of the UV radiometer reading.

The UVIATOR program calculates the solar zenith angle, Θ_0, for each measurement as a function of the measurement location (latitude and longitude) and the GMT of the reading. The total Ozone column density, O_3, is automatically retrieved from the OMI or TOMS satellite data archives. Note, that TOMS data are daily mean values only. UVIATOR offers plug-ins to allow the use of other Ozone column observation data, such as from the Kipp & Zonen Brewer.

Finally, the UVIATOR program corrects the UVS measurements using the appropriate solar zenith angles and Ozone column densities and makes a new data file.

References:

[1] WMO/GAW Report No. 120: WMO – UMAP Workshop on Broad-Band UV Radiometers, Garmisch-Partenkirchen, Germany, 1996. WMO TD – No. 894.

[2] WMO/GAW Report No. 141: Report of the LAP/COST/WMO Intercomparison of Erythemal Radiometers, Thessaloniki, Grece, 1999. WMO TD – No. 1051.

[3] TUV discrete ordinate radiative transfer model, Madronich et al. 1998, http://www.acd.ucar.edu/TUV/

[4] McKinley, A.F. and B.L. Diffey, 1987: A reference action spectrum for ultraviolet induced erythema in human skin. CIE J., 6, 17-22.

[5] Schreder, J., J. Gröbner, A. Los, and M. Blumthaler, 2004: Intercomparison of monochromatic source facilities for the determination of the relative spectral response of erythemal broadband filter radiometers. Optics Letters, 29(13).

5 MAINTENANCE AND RECALIBRATION

The quartz dome should be cleaned regularly. You may use a mild window cleansing agent which must be generously rinsed with clear water and wiped dry with a clean cloth.

The quartz dome can be replaced when damaged. In order to replace the dome, loosen the 6 screws in the outer ring and remove the ring and dome. Take care not to touch the white diffuser. Clean the surface of the housing and check the condition of the O-ring and re-place it when necessary. Re-assemble using the new dome and mounting ring in the reverse order.

Another periodic check is to ensure that the instrument is level and that the silica gel is still coloured orange. When the orange silica gel in the drying cartridge is turned completely transparent (normally after several months), it must be replaced by fresh silica gel as supplied in the small refill packs. The contents of one pack is sufficient for one complete refill.

Periodic recalibration of the sensors is recommended and provided by Kipp & Zonen. We recommend a recalibration interval of 12 months.

6 PART NUMBERS, OPTIONS AND SPARES

PARTS		
UVS RADIOMETERS		**Part No.**
UV-S-A-T	UV-A	0354920
UV-S-B-T	UV-B	0354925
UV-S-E-T	UV-E (Erythemally active)	0354930
UV-S-AB-T	(dual band)	0354940
UV-S-AE-T	(dual band)	0354945

SPARES	Part No.
Extra connector without cable for UV-S-X-T	2523146
Waterproof 8 pin plug + 15 m cable	0362622
Waterproof 8 pin plug + 25 m cable	0362623

OPTIONS	Part No.
CVP 2 Power Supply for UVS radiometers 115 / 230V input, 12 VDC output	0349401

APPENDIX I:
ERYTHEMAL ACTION SPECTRUM
ACCORDING TO CIE 1987 (DIN 5050)

λ[nm]	Weighting	λ[nm]	Weighting	λ[nm]	Weighting
290	1.000E+00	327	0.188E-02	364	0.422E-03
291	1.000E+00	328	0.151E-02	365	0.407E-03
292	1.000E+00	329	0.141E-02	366	0.394E-03
293	1.000E+00	330	0.136E-02	367	0.380E-03
294	1.000E+00	331	0.132E-02	368	0.367E-03
295	1.000E+00	332	0.127E-02	369	0.355E-03
296	1.000E+00	333	0.123E-02	370	0.343E-03
297	1.000E+00	334	0.119E-02	371	0.331E-03
298	1.000E+00	335	0.115E-02	372	0.320E-03
299	0.805E+00	336	0.111E-02	373	0.309E-03
300	0.649E+00	337	0.107E-02	374	0.299E-03
301	0.522E+00	338	0.104E-02	375	0.288E-03
302	0.421E+00	339	0.100E-02	376	0.279E-03
303	0.339E+00	340	0.966E-03	377	0.269E-03
304	0.273E+00	341	0.933E-03	378	0.260E-03
305	0.220E+00	342	0.902E-03	379	0.251E-03
306	0.177E+00	343	0.871E-03	380	0.243E-03
307	0.143E+00	344	0.841E-03	381	0.234E-03
308	0.115E+00	345	0.813E-03	382	0.226E-03
309	0.925E-01	346	0.785E-03	383	0.219E-03
310	0.745E-01	347	0.759E-03	384	0.211E-03
311	0.600E-01	348	0.733E-03	385	0.204E-03
312	0.483E-01	349	0.708E-03	386	0.197E-03
313	0.389E-01	350	0.684E-03	387	0.191E-03
314	0.313E-01	351	0.661E-03	388	0.184E-03
315	0.252E-01	352	0.638E-03	389	0.178E-03
316	0.203E-01	353	0.617E-03	390	0.172E-03
317	0.164E-01	354	0.596E-03	391	0.166E-03
318	0.132E-01	355	0.575E-03	392	0.160E-03
319	0.106E-01	356	0.556E-03	393	0.155E-03
320	0.855E-02	357	0.537E-03	394	0.150E-03
321	0.689E-02	358	0.519E-03	395	0.145E-03
322	0.555E-02	359	0.501E-03	396	0.140E-03
323	0.447E-02	360	0.484E-03	397	0.135E-03
324	0.360E-02	361	0.468E-03	398	0.130E-03
325	0.290E-02	362	0.452E-03	399	0.126E-03
326	0.233E-02	363	0.437E-03	400	0.122E-03

APPENDIX II: CONVERSION OF OUTPUT VOLTAGE FOR INTERNAL TEMPERATURE

Relation between the voltage at the temperature output (connector pin 4, yellow wire) and the internal temperature for all models
UVS-A-T, UVS-B-T, UVS-E-T, UV-S-AB-T, UV-S-AE-T:

V	°C
0.5	-23
0.6	-19
0.7	-16
0.8	-13
0.9	-10
1.0	-7
1.1	-5
1.2	-2
1.3	0
1.4	2
1.5	5
1.6	7
1.7	9

V	°C
1.8	11
1.9	13
2.0	15
2.1	17
2.2	19
2.3	21
2.4	23
2.5	25
2.6	27
2.7	29
2.8	31
2.9	34
3.0	36

APPENDIX III: RECALIBRATION SERVICE

Solar Radiation Measurement Instruments

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 every two years. The exception to this is the UVS Series of UV Radiometers, where recalibration is recommended annually.

Recalibration can be carried out at Kipp & Zonen to the original factory procedures using traceable methods. Here, recalibration to the highest standards can be performed at low cost. Recalibration can usually be performed within four weeks. Urgent recalibration may be possible in a shorter time, subject to production scheduling restrictions.

Kipp & Zonen will confirm the date for recalibration when the instrument is received and its condition checked.

For your convenience we have added a form that you can fax or e-mail to us to schedule the recalibration of your instrument(s) at Kipp & Zonen.

KIPP & ZONEN
SINCE 1830

RECALIBRATION FORM

NAME :
COMPANY / INSTITUTE :

ADDRESS :

POST CODE + CITY :
COUNTRY :
TEL :
FAX :
E-MAIL :

☐ 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

Fax to: **+31-15-2620-351**
Or
E-mail to: **info@kippzonen.com**

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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