CM 6B & CM11
Pyranometer Sensors

User Guide

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- Batteries
- Any product which has been subjected to misuse, neglect, acts of God or damage in transit.

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Contents

Tables

Figures

CM6B & CM11 Pyranometer Sensors

These Kipp & Zonen thermopile pyranometers comply with the international standard (ISO 9060) and offer high-accuracy measurements of direct and diffuse solar radiation. The CM6B meets the WMO 'first class' specification and is ideal for routine measurements, agricultural stations etc. The CM11 is intended for high accuracy total global, or diffuse sky, solar radiation measurement research on a plane/level surface, and is fully compliant with the ISO-9060 Secondary Standard pyranometer performance category (highest ISO performance criteria for a pyranometer).

The thermocouple thermopile on both instruments is rotationally symmetrical and is housed under K5 glass domes. A white screen stops the body of the pyranometer heating up and a drying cartridge stops condensation on the inside of the sensor. A spirit level and levelling screws are provided.

1. WMO Classifications

The response of a pyranometer is affected by several factors, including the temperature, the irradiance level and the angle of incidence. Taking all such factors into account, the CM 6B is classified as ‘first class’ and the CM11 as 'secondary standard', as shown in Table 1, below.

Table 1 WMO Classification of Pyranometers

Specification	Secondary Standard	First Class	Second Class
Resolution (Wm^{-2})	±1	±5	±10
Stability (% full scale per year)	±1	±2	±5
Cosine response (% deviation from ideal at 10° solar elevation on a clear day)	<±3	<±7	<±15
Azimuth response (% deviation from the mean at 10° solar elevation on a clear day)	<±3	<±5	<±10
Temperature response (max. % error due to change of ambient temperature over operating range)	±1	±2	±5
Non-linearity (% of full scale)[2]	±0.5	±2	±5
Spectral sensitivity (% deviation from mean absorptance 0.3 to 3m) – see Appendix B	±2	±5	±10
Response Time (99% response)	< 25s	< 1 min	< 4 min

2. Specifications

	CM6B	CM11
ISO Classification	First Class	Secondary Standard
ISO Specifications		
Response Time 95% (seconds)	18	12
Zero Offsets*		
*thermal radiation (200 W^{m-2})	< 15 Wm^{-2}	< 7 Wm^{-2}
*temperature change (5K/hr)	< ±4 Wm^{-2}	< ±2 Wm^{-2}
Non-stability (% change/year)	± 1 max	± 0.5 max
Non-linearity (at 1000 W^{m-2})	< ±1.2%	< ±0.6%
Directional error (at 1000 W^{m-2})	< ±20 Wm^{-2}	< ±10 Wm^{-2}
Temperature dependence of sensitivity	±2% (-10 to + 40°C)	±1% (-10 to + 40°C)
Tilt response (± 80°) at 1000 W^{m-2}	< ± 1%	< ± 0.25%
Special Features		
Response time **99%** (seconds)	55	24
Level accuracy (degrees)	0.5	0.1 (radiometrically levelled relative to the sensor)
Test certificate	Sensitivity	Sensitivity & directional error
Other specifications		
Sensitivity µV/ W^{m-2}	9-15	4-6
Impedance (Ω)	70-100	700-1500
Operating Temperature	-40 to +80°C	-40 to +80°C
Cable length	10m	10m
Spectral range (50% points, nm)	305-2800	305-2800
Expected signal output in atmospheric application	0-25mV	0-10mV
Maximum irradiance	2000 Wm^{-2}	4000 Wm^{-2}
Expected accuracy for daily sums	± 5%	± 3%

3. Installation

Site the pyranometer carefully, ideally avoiding any obstructions above the plane of the sensing element, while allowing easy access for maintenance. If this is not possible, choose a site where any obstruction over the azimuth range between earliest sunrise and latest sunset has an elevation not exceeding 5°. (The apparent sun diameter is 0.5°.)

This is important for accurate measurement of direct solar radiation. 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 only 0.8%.

It is important to mount the pyranometer such that a shadow will not be cast on it at any time.

NOTE Hot streams of exhaust gas (>200°C) will produce radiation in the spectral range of the CM6B and CM11. The pyranometers should also be kept away from light-coloured walls or other objects likely to reflect sunlight onto them.

In principle, no special rotational orientation of the instrument is required due to the rotational symmetry of the sensor. The WMO recommend that emerging cables be pointed to the nearest Pole to minimise heating of the electrical connections.

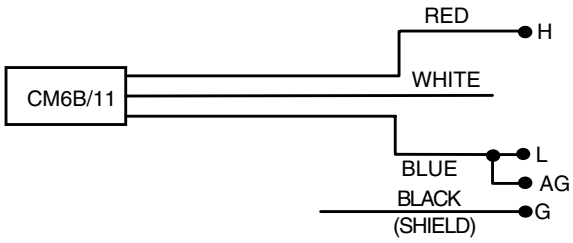
Accurate measurement of global radiation requires proper levelling of the thermocouple surface. Level the instrument as follows:

1. Remove the white cover by undoing the retaining screws.
2. Turn the levelling screws to bring the bubble of the spirit level within the ring. (For easy levelling first use the screw nearest the spirit level.)
3. Replace the white cover.

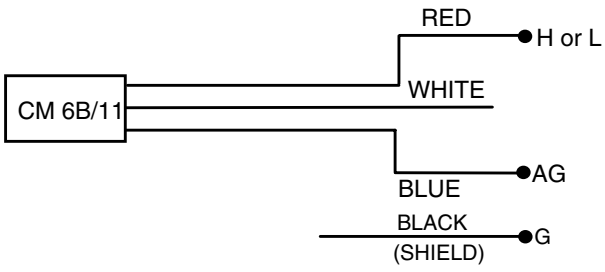
Isolate the pyranometer thermally from the mounting stand, e.g. by placing it on its levelling screws.

3.1 Wiring

Connect the CM6B / CM11 to the datalogger as shown in Figure 1. The black (shield) wire should be connected to datalogger ground as shown, but the white (case) wire should *not* be connected. Instead, earth the pyranometer case by ensuring that there is electrical contact between the mounting screws and an earth point. The pyranometer contains a surge arrestor which isolates the shield from the case and breaks down at 90V. This means that electrical transients can go straight to earth via the surge arrestor and the case, rather than travelling down a long cable to the datalogger earth.



(a) Differential Measurement



(b) Single-Ended Measurement

Figure 1 CM6B / CM11 Wiring

Notes for Figure 1:

1. AG refers to Analogue Ground on the CR10X and CR510, which is the same as ground (⏚) for the CR23X and CR7.
2. For the differential measurement, the low side of the differential channel is connected to analogue ground in order to keep the output signal inside the common mode range of the datalogger.

4. Programming

The CM 6B and CM11 output a low level voltage ranging from 0 to a maximum of about 10 to 25mV depending on the calibration factor and radiation level. A differential voltage measurement (Instruction 2) is recommended because it has better noise rejection than a single-ended measurement. If a differential channel is not available, a single-ended measurement (Instruction 1) can be used. The acceptability of a single-ended measurement can be determined by simply comparing the results of single-ended and differential measurements made under the same conditions.

4.1 Input Range

The output voltage is usually between 0.9 and 1.5mV per 100Wm^{-2} for the CM6B and between 0.4 and 0.6mV per 100Wm^{-2} for the CM11.

Select the input range as follows:

1. Estimate the maximum expected input voltage by dividing the maximum expected irradiance in 100Wm^{-2} by the calibration factor.
2. Select the smallest input range which is greater than the maximum expected input voltage. Normally the 15mV range for the CR7, and the 25mV range for the CR10X are suitable.

The parameter code for the input range also specifies the measurement integration time. The slow or 50Hz rejection integration gives a more noise-free reading. A fast integration takes less power and allows for faster throughput.

4.2 Multiplier

The multiplier converts the millivolt reading to engineering units. The calibration certificate supplied by the manufacturer normally states the output of the sensor (c) as a number of microvolts (V x 10^{-6}) per Wm^{-2}. As the datalogger voltage measurement instructions give a default output in mV, the following equation should be used to calculate the multiplier (m) to give the readings in Wm^{-2}:

$$m = 1000/c$$

Other units can be used by adjusting the multiplier as shown in Table 2.

Table 2 Multipliers Required for Flux Density and Total Fluxes

Units	Multipliers	
kJm^{-2}	m*t*0.001	(total fluxes)
kWm^{-2}	m*0.001	(flux density)
cal cm^{-2}	m*t*0.0239*0.001	(total fluxes)
cal cm^{-2} min^{-1}	m*1.434*0.001	(flux density)

m = calibration factor in Wm^{-2}/mV

t = datalogger program execution interval in seconds

4.3 Output Format Considerations

The largest number the datalogger can store in Final Storage is 6999 in low resolution and 99999 in high resolution. If the measurement value is totalized, there is some danger of overranging the output limits, as shown in the following example:

Example

Assume that daily total flux is desired, and that the datalogger scan rate is 1 second. With a multiplier that converts the readings to units of kJm^{-2} and an average irradiance of $.5kWm^{-2}$, the maximum low resolution output limit will be exceeded in less than four hours.

Solution 1 – Change the multiplier in the instruction to (m*0.0001). This will totalise MJm^{-2} instead of kJm^{-2}.

Solution 2 – Record the average flux density and later multiply the result by the number of seconds in the output interval to arrive at total flux.

Solution 3 – Record the total flux using the high resolution format. The drawback to high resolution is that it requires four bytes of memory per data point, consuming twice as much memory as low resolution.

5. Maintenance

Inspect and clean the outer dome at regular intervals, e.g. every week or so. Clean any accumulated dust, etc. off the domes and housing using a soft damp cloth.

On clear, windless nights the outer dome temperature of horizontally placed pyranometers can fall as low as the dew point temperature of the air, due to infra-red radiation exchange with the cold sky. (The effective sky temperature can be 30°C lower than the ground temperature, which results in an infra-red emission of $-150Wm^{-2}$). If this happens, 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 diffuser and can increase the pyranometer signal by up to 50% in the first hours after sunrise.

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

The calibration of the pyranometer may drift with time and exposure to radiation. This can be caused, for example, by deterioration of the black paint. Recalibration every two years is recommended, and the sensor should be returned to Campbell Scientific for this.

Appendix A Principle of Operation

The thermal detector in the CM6B/CM11 responds to the total power absorbed, and theoretically it is non-selective as to the spectral distribution of the radiation. This implies that the naked thermal detector is also sensitive to long wave infrared radiation (thermal radiation λ >3000nm) from the environment.

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

The rise of temperature is easily affected by wind, rain and thermal radiation losses to the environment ('cold' sky). Therefore the detector is shielded by two glass domes. Glass domes allow equal transmitting of the direct solar component for every position of the sun on the celestial sphere. The transmission characteristics of the glass limit the spectral range of the pyranometer.

NOTE As with any thermopile sensor, rapid changes in temperature can cause small transient offsets to appear on the sensor output. This can result in small negative readings during the night.

Appendix B Specification Details

B.1 Temperature Dependence

Figure B-1shows how the sensitivity can vary with temperature. The shaded region shows the possible range of variation and the dashed line shows a typical curve for a single CM6B sensor. The CM11 error will be approximately half that shown in Figure B-1.

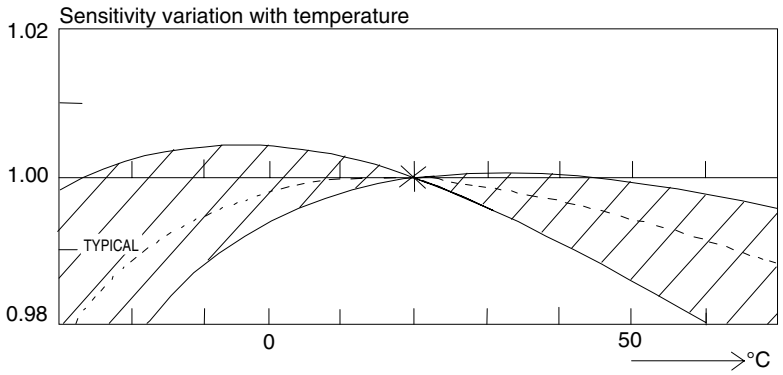


Figure B-1 Variation of Sensitivity with Temperature

B.2 Non-Linearity

Non-linearity is a measure of how the sensitivity varies with irradiance level. Figure B-2 shows this variation for horizontal and tilted CM6B sensors. The CM11 error will be approximately half that shown.

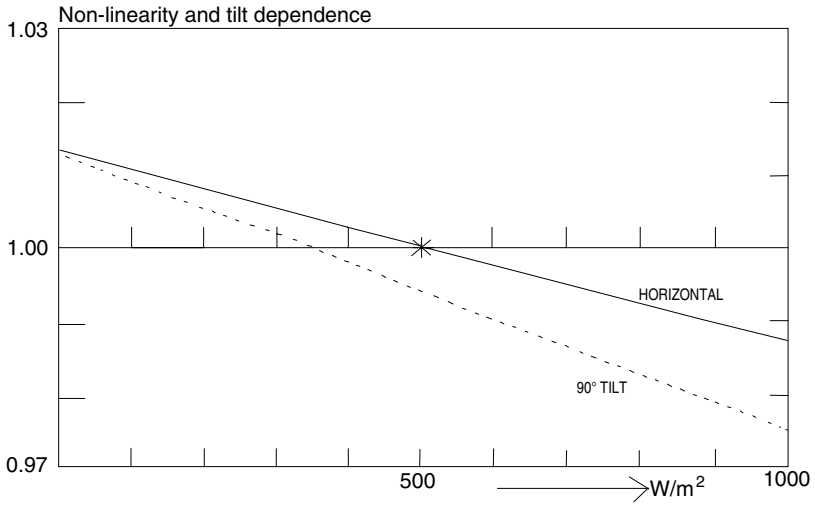


Figure B-2 Variation of Sensitivity with Irradiance

B.3 Spectral Selectivity

This is the product of the spectral absorptance of the black coating and the spectral transmittance of the glass domes.

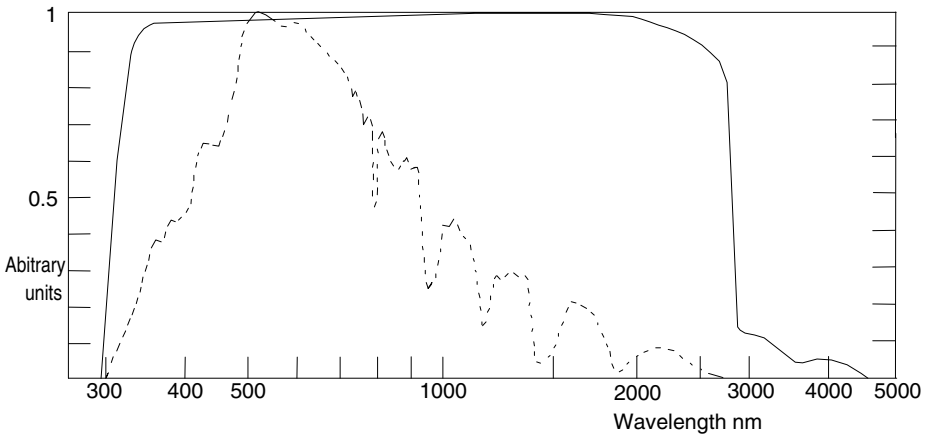


Figure B-3 Spectral Selectivity of CM 6B

The solid line shows the relative spectral transmittance of two pyranometer domes. (Four surface reflections and index change with wavelength are taken into account.)

The dashed line shows the spectral distribution of solar radiation at sea level. Sun at Zenith (Airmass 1).