

CMP10x Pyranometer

Operational Manual



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1 Scope of supply

The following items are included with CMP10x pyranometers:

- Pyranometer
- Sun shield
- Calibration certificate (with temperature response and directional response for CMP10x)
- Instruction sheet

2 Order numbers and variant code

2.1 Product variants

| Variant | Order number |
|---------|--------------|
| CMP10x | 0379915 |

2.2 Accessories and spare parts

Accessories

| Item | Order number |
|--|--------------|
| CVF 4 Ventilation Unit, no plug, no cable | 0378910-000 |
| CMF1 Mounting Fixture for 1 or 2 unventilated radiometers | 0362700 |
| CMF4 Mounting Fixture | 0362703 |
| Glare Screen Kit for downwards facing unventilated radiometers | 0305722 |
| Glare Screen Kit for downwards facing ventilated radiometers | 0305725 |
| AMPBOX signal amplifier, standard gain setting | 0365900 |
| METEON Irradiance Meter and Data Logger | 0365910 |
| Fixed Feet | 0362705 |
| CM121B Shadow Ring for unventilated radiometers | 0346900 |
| CM121C Shadow Ring for ventilated radiometers | 0346901 |
| Waterproof 4-pin plug only | 2523145 |
| 10 m cable, pre-wired with waterproof 4-pin plug | 0362611 |
| 25 m cable, pre-wired with waterproof 4-pin plug | 0362613 |
| 50 m cable, pre-wired with waterproof 4-pin plug | 0362614 |

3 About this manual

3.1 General signs and symbols

The signs and symbols used in the operational manual have the following meaning:

Practical tip

 This symbol indicates important and useful information.

Action

- ✓ Prerequisite that must be met before performing an action.
- ▶ Step 1
 - ⇒ Intermediate result of an action
- ▶ Step 2
 - ⇒ Result of a completed action

List

- List item, 1st level
 - List item, 2nd level

3.2 Explanation of warnings

To avoid personal injury and material damage, you must observe the safety information and warnings in the operating manual. The warnings use the following danger levels:

WARNING

WARNING

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in death or serious injuries.

CAUTION

CAUTION

This indicates a potentially hazardous situation. If the hazardous situation is not avoided, it may result in moderately serious or minor injuries.

NOTICE

NOTE

This indicates a situation from which damage may arise. If the situation is not avoided, products may be damaged.

4 General safety instructions

4.1 Intended use

The pyranometer is used to measure and report the solar radiation.

4.2 Potential misuse

Any use of the product that does not comply with the intended use, be this intentional or negligent, is forbidden by the manufacturer.

- ▶ Use the product only as described in the operational manual.

4.3 Personnel qualification

The equipment described in this manual must be installed, operated, maintained and repaired by qualified personnel only.

- ▶ Obtain training from OTT HydroMet if necessary.

4.4 Operator obligations

The installer is responsible for observing the safety regulations. Unqualified personnel working on the product can cause risks that could lead to serious injury.

- ▶ Have all activities carried out by qualified personnel.
- ▶ Ensure that everybody who works on or with the product has read and understood the operational manual.
- ▶ Ensure that safety information is observed.
- ▶ File the operational manual together with the documentation of the entire system and ensure that it is accessible at all times.
- ▶ The operational manual is part of the product, forward the operational manual together with the product.

4.5 Personnel obligations

To avoid equipment damage and injury when handling the product, personnel are obliged to the following:

- ▶ Read the operational manual carefully before using the product for the first time.
- ▶ Pay attention to all safety information and warnings.
- ▶ If you do not understand the information and procedure explanations in this manual, stop the action and contact the service provider for assistance.
- ▶ Wear the necessary personal protective equipment.

4.6 Risk of burns due to hot surfaces

If the ambient temperature is too high, the metal parts of the housing may heat up (> 60 °C). Touching the housing can cause burns.

- ▶ Do not touch the housing.
- ▶ Wear protective gloves during installation and maintenance.

4.7 Correct handling

If the product is not installed, used and maintained correctly, there is a risk of injury. The manufacturer does not accept any liability for personal injury or material damage resulting from incorrect handling.

- ▶ Install and operate the product under the technical conditions described in the operational manual.
- ▶ Do not change or convert the product in any way.
- ▶ Do not perform any repairs yourself.
- ▶ Get OTT HydroMet to examine and repair any defects.
- ▶ Ensure that the product is correctly disposed of. Do not dispose of it in household waste.

4.8 Certification

CE (EU)

The equipment meets the essential requirements of EMC Directive 2014/30/EU.

FCC (US)

FCC Part 15, Class "B" Limits

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

IC (CA)

Canadian Radio Interference-Causing Equipment Regulation, ICES-003, "Class B"

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

5 Product description

5.1 Design and function

The CMP series instruments are radiometers designed for measuring short-wave irradiance on a plane surface (irradiance, W/m^2) which results from the sum of the direct solar radiation and the diffuse sky radiation incident from the hemisphere above the instrument.

To achieve the required spectral and directional characteristics CMP pyranometers use thermopile detectors and glass domes. The thermopile responds to the total energy absorbed by black surface coating, which is spectrally non-selective. The thermopile warms up and the heat generated flows through a thermal resistance to a heat-sink, the pyranometer housing. The temperature difference across the thermal resistance of the detector is converted into a small voltage as a function of the absorbed irradiance. Therefore the pyranometers do not require power to operate.

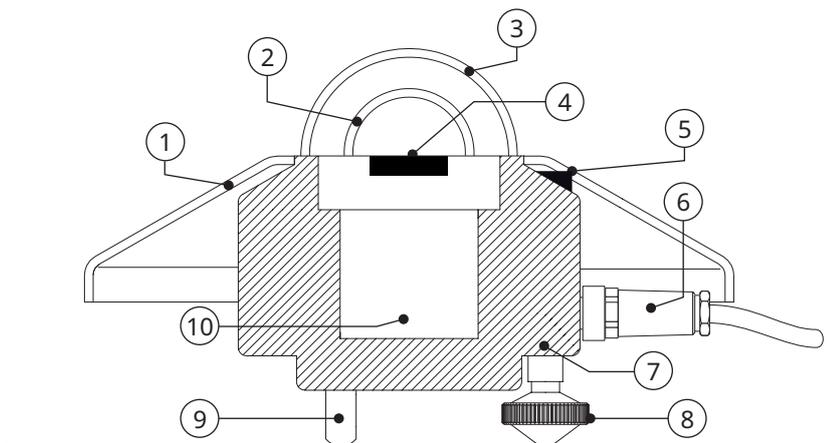
The rise of temperature in the thermopile is easily affected by wind, rain and thermal radiation losses to the environment and the delicate black coating must be protected. Therefore the detector is shielded by one or two domes. These domes allow equal transmittance of the direct solar radiation component for every position of the sun in the hemisphere above the detector. The internal desiccant prevents condensation on the inner sides of the domes, which can cool down considerably on clear windless nights.

The pyranometers have built-in bubble levels and adjustable leveling feet. Snap-on sun shields reduce solar heating of the housings. The waterproof connectors have gold-plated contacts.

The pyranometers can be delivered with an optional waterproof plug pre-wired to a signal cable. The cables are available in 10 m, 25 m, and 50 m lengths. The instruments can also be ordered with a plug only, for the user to fit their own cable.

The CMP series albedometer kit consist of two pyranometers. The upper measures incoming global solar radiation and the lower measures solar radiation reflected from the surface below, when the two signal outputs have been converted to irradiance in W/m^2 , the albedo can be simply calculated. Albedometers are constructed using two pyranometers, an albedometer mounting rod, and a glare screen to prevent direct sunlight from below the horizon entering the lower pyranometer.

5.2 Product overview



CMP10x pyranometer

- | | | | |
|---|---------------------|----|--------------------------|
| 1 | Sun shield | 6 | Connector |
| 2 | Inner glass dome | 7 | Housing |
| 3 | Outer glass dome | 8 | Adjustable leveling feet |
| 4 | Thermopile detector | 9 | Fixed foot |
| 5 | Bubble level | 10 | Internal desiccant |

6 Transport, storage, and unpacking

6.1 Transport

- ▶ Transport the product always in its original packaging.
- ▶ Ensure that the product is not mechanically stressed during transport.

6.2 Storage

- ▶ Store within specified temperature ranges.
- ▶ Store in dry area.
- ▶ Store in original box where possible.

6.3 Unpacking

- ▶ Carefully remove the product from the packaging.
- ▶ Check that the delivery is complete and undamaged.
- ▶ If you find any damage or if the delivery is incomplete, then immediately contact your supplier or manufacturer.
- ▶ Keep the original packaging for any further transportation.

7 Installation and commissioning

7.1 Planning installation

For the solar irradiation to be measured in the entire photovoltaic system, it is necessary to position several pyranometers in the system. The number of pyranometers required depends on the system's performance and ambient conditions.

The minimum number of sensors required for a IEC 61724-1 Class A system is defined as follows:

- 1 sensor for each monitoring point to measure the following values:
 - In-plane irradiance (POA)
 - Global horizontal irradiance
- In addition, the following sensors are used:
 - 1 horizontal albedo sensor
or
 - 3 in-plane rear-side irradiance sensors

The number of monitoring points depends on the system size, as seen in the table below:

| System size (AC) in MW | Number of monitoring points | Number of pyranometers |
|------------------------|------------------------------------|------------------------|
| < 40 | 2 | 6 to 10 |
| ≥ 40 to < 100 | 3 | 9 to 15 |
| ≥ 100 to < 300 | 4 | 12 to 20 |
| ≥ 300 to < 500 | 5 | 15 to 25 |
| ≥ 500 to < 700 | 6 | 18 to 30 |
| ≥ 700 | 7, plus 1 for every further 200 MW | 21+ to 35+ |

7.2 Mechanical installation

7.2.1 Preparatory work

- ▶ If necessary contact the OTT HydroMet service personnel.

i The internal desiccant of the CMP10x is operational for 10 years after the last calibration date at an official OTT HydroMet Calibration Lab, shown on the instrument label and calibration certificate.

7.2.2 Required tools and aids

The following tools and aids are required:

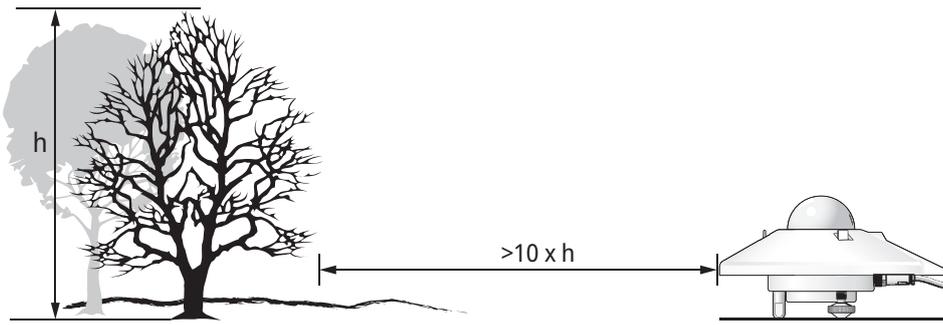
- Allen key, 4 mm
- wrench, 8 mm

7.2.3 Installation for measuring global radiation

7.2.3.1 Choosing a site

There should be no obstructions in the field of view above the instrument's sensor element. If this is not possible, the location of the instrument must be chosen to ensure that obstacles do not rise by more than 5 degrees above the azimuth range between sunrise after the shortest night and sunset on the longest day.

The 5 degrees correspond to a minimum distance from the instrument to the obstacle of 10 times the height of the obstacle:

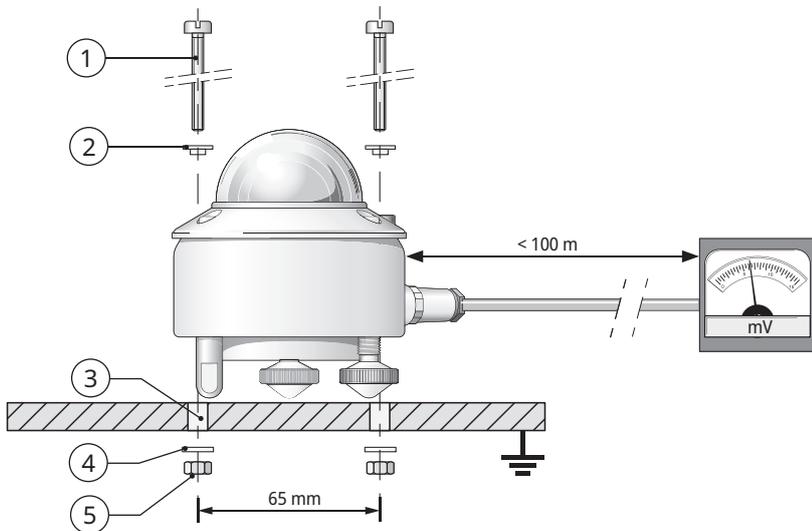


Minimum distance from instrument to obstacle

The minimum distance is important for measuring the direct radiation. The diffuse solar radiation is not so affected by obstacles near the horizon. An obstacle to the field of view that rises 5 degrees over the entire azimuth range of 360 degrees reduces the diffuse radiation directed downwards by only 0.8 %.

- ▶ Position the instrument in such a way that no shadows fall on it, for instance from masts.
- ▶ Avoid hot exhaust gases with a temperature of over 100 °C in the proximity of the instrument. It can cause measurement deviations.
- ▶ Do not position the instrument in front of light-colored walls or any other objects that reflect the sunlight or emit short-wave radiation.

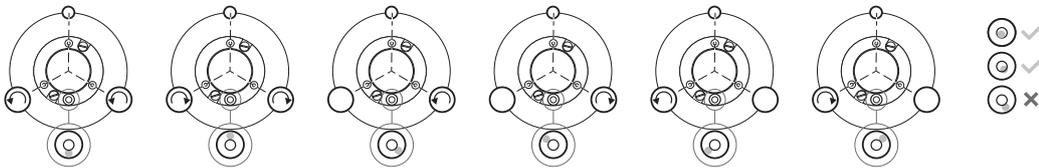
7.2.3.2 Mounting instrument



- | | | | |
|---|---------------------------|---|-----------------|
| 1 | 2x M5 x 80 mm screws | 4 | 2x flat washers |
| 2 | 2x nylon insulating rings | 5 | 2x nuts |
| 3 | 2x Ø 5.2 mm | | |

- ▶ To insulate the instrument against the temperature of the mounting plate, place the instrument on the fixed foot and the two leveling feet.
- ▶ Position the instrument in such a way that the nuts are located at a distance of 2 to 3 mm from the mounting plate.
- ▶ Ensure that the instrument is fixed.

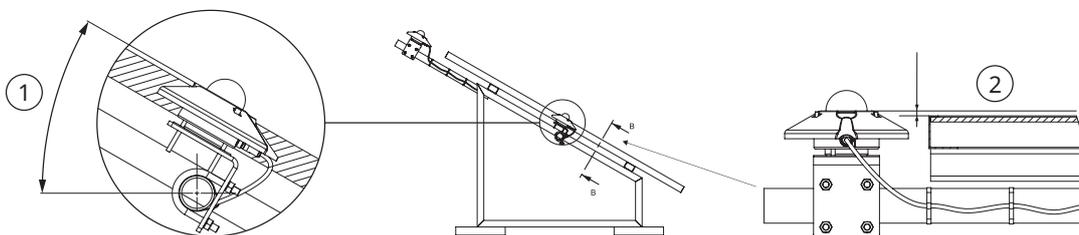
- ▶ Ensure that the instrument is not in the shade.
- ▶ When installed horizontally, point the cable connector towards the nearest pole to reduce the UV exposure on the cable.
- ▶ In order to align the instrument horizontally, rotate the leveling feet until at least half the spirit level bubble is in the inner ring.



- ▶ Fix the instrument with the screws, ensure that the instrument retains the correct alignment.
- ▶ To prevent corrosion between the screws and the instrument housing, ensure that the nylon insulating rings are fixed.
- ▶ Insert the connector with the cable into the instrument's connection socket.
- ▶ Tighten the locking ring hand tight.
NOTICE! The seal may be damaged by overtightening!
- ▶ Fix the cable in such a way that the cable doesn't move or cast a shadow on the instrument.
- ▶ Fix the sun shield.

7.2.4 Installation for measuring global radiation on sloping surfaces

In a photovoltaic system, the pyranometer can be installed at the same zenith angle and azimuth angle as the modules. The pyranometer can be mounted using the adjustable leveling feet or using a set of fixed feet that are suitable for mounting on sloping surfaces.



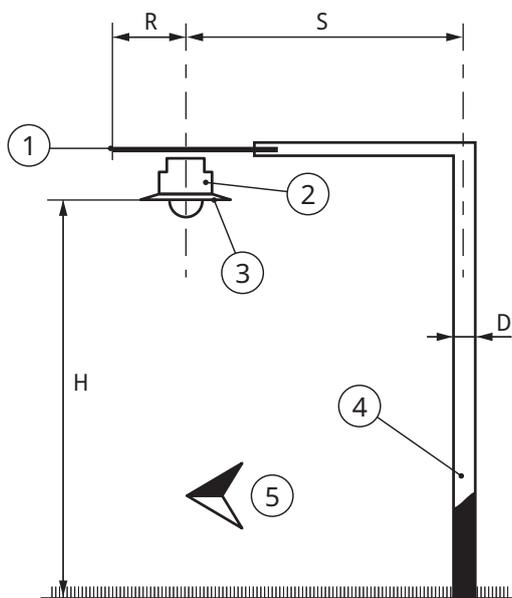
1 Zenith angle $\pm 1^\circ$

2 Azimuth angle $\pm 2^\circ$

- ▶ Place the pyranometer on a horizontal surface.
- ▶ Ensure that the leveling feet protrude as far as the adjustable foot.
- ▶ Level the pyranometer.
- ▶ Label the pyranometer with a note stating that the feet have been set.
- ▶ Alternatively, remove the leveling feet and mount the fixed feet.
- ▶ Label the pyranometer with a note stating that the fixed feet are suitable for sloping installation.
- ▶ Fix the pyranometer on the sloping surface.
- ▶ Point the cable connector downwards to reduce moisture exposure around the connector.

7.2.5 Installation for measuring reflected radiation

In inverted position the pyranometer measures the reflected global radiation.



- 1 Mounting plate
- 2 Pyranometer
- 3 Glare screen
- 4 Mast (black)
- 5 Equator

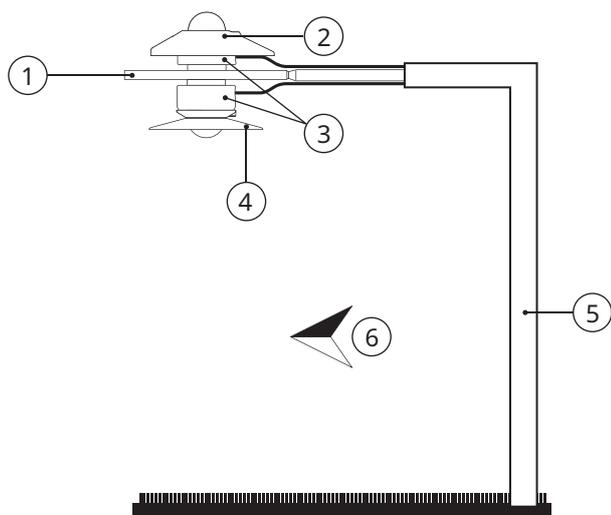
The mounting plate prevents the pyranometer from being heated by solar radiation. The optional glare screen has an angle of 5 degrees and prevents direct radiation on the glass dome during sunrise and sunset.

The mounting device must not excessively disrupt the pyranometer's field of vision. The mast blocks part of the field of view. In addition, depending on the position of the sun, the mast can cast a shadow in the field of view of the instrument, or it could reflect radiation. In the worst case (sun at its zenith), the pyranometer shadow reduces the signal by a factor of R^2/H^2 . As a rule of thumb, a black shadow under the pyranometer with a radius of $0.1 \times H$ reduces the signal by 1%. 99% of the signal comes from a range with a radius of $10 \times H$.

- ▶ Level the mounting plate well, as the pyranometer will be mounted without feet.
- ▶ Fix the pyranometer to the mounting plate at a height of between 1 and 2 meters above an even surface such as short grass.

7.2.6 Installation for measuring albedo

An albedometer consists of two identical pyranometers that measure the incident radiation and the radiation reflected by the surface below. Albedo is the ratio of the two radiation measurements and varies from 0 (dark) to 1 (bright).

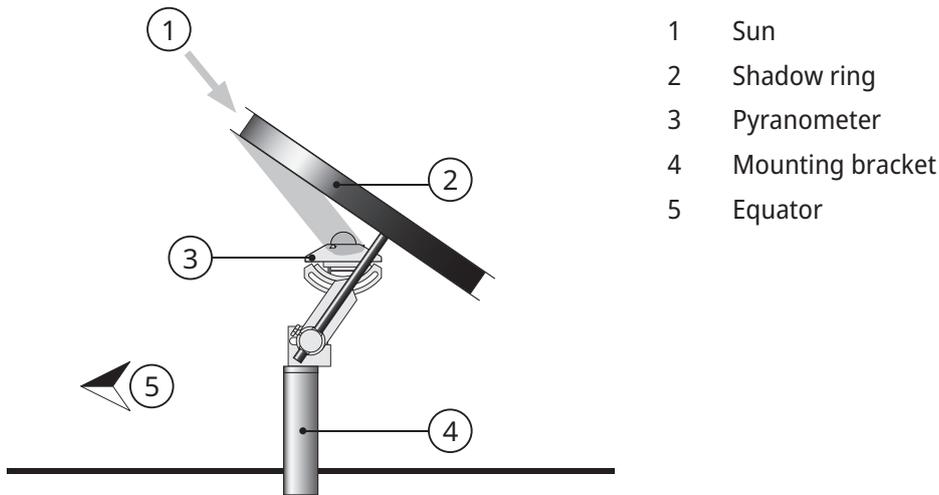


- 1 Albedo mounting plate
- 2 Sun shield
- 3 Pyranometer
- 4 Glare screen
- 5 Mast
- 6 Equator

- ▶ Mount the upper pyranometer.
- ▶ Mount the lower pyranometer.

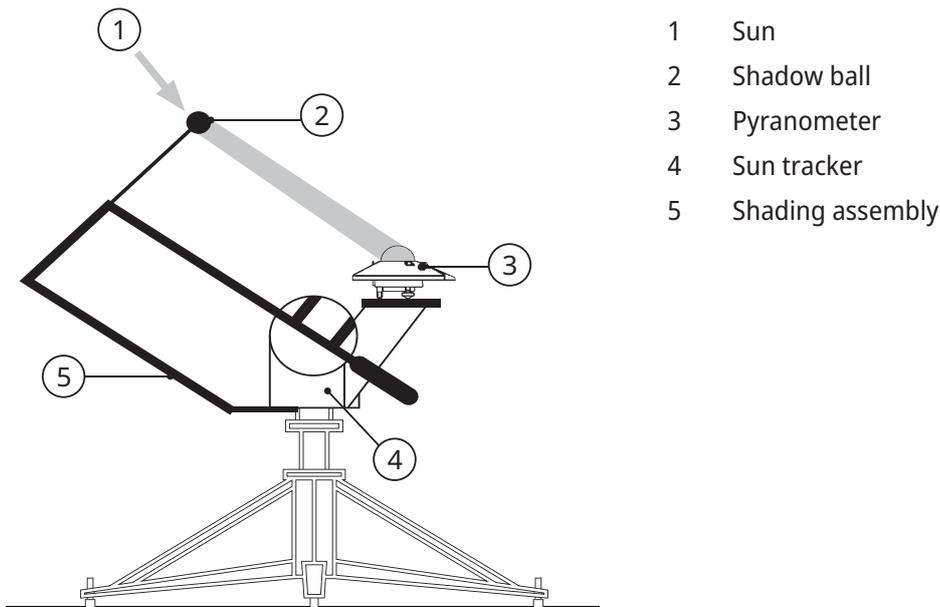
7.2.7 Installation for measuring diffuse radiation

For the diffuse radiation to be measured, the direct radiation on the pyranometer's glass dome must be blocked. The direct radiation can be blocked using a static shadow ring or a two-axis automatic sun tracker.



Mounting static shadow ring

Because the sun moves across the sky, the static shadow ring interrupts part of the diffuse radiation and needs to be regularly adjusted (every few days). The shadow ring obstructs part of the sky, reducing the amount of diffuse radiation reaching the sensor. The data can be corrected for the obstruction of the sky.



Mounting automatic sun tracker

The automatic sun tracker uses the information regarding its location and the time to calculate the position of the sun. This allows the tracker to be oriented exactly towards the sun whatever the weather. Using a shadowing fixture on the tracker, the pyranometer's glass dome can be shaded all year round without any need for adjustment.

7.3 Electrical installation

7.3.1 Electrical connections

CMP10x is fitted with a 4-pin connector and 4-wires shielded cable.



4-pin instrument plug

Pin assignment

| Wire Number | Color | Function |
|-------------|--------|---------------------|
| 1 | Red | Irradiance + (High) |
| 2 | Blue | Irradiance - (Low) |
| 3 | Green | Thermistor + (High) |
| 4 | Yellow | Thermistor - (Low) |

7.3.2 Grounding pyranometer

Lightning can induce high voltages in the shield of the cable but these will be led off at the pyranometer or readout equipment. The shield of the cable is connected to the aluminium pyranometer housing through the connector body.

- ▶ Secure the pyranometer with the leveling screws to a metal support with a good connection to ground, e.g. to a lightning conductor.
- ▶ Do not connect the cable shield at the readout equipment if the pyranometer is properly grounded.
- ▶ If there is no good ground connection at the pyranometer, then connect the shield at the cable end to ground at the readout equipment.

7.3.3 Radiation signal output

The pyranometer produces a low-level analogue voltage output and has a unique sensitivity, which is given on the serial number label on the instrument and on the calibration certificate. The sensitivity is in the range of 7 to 16 $\mu\text{V}/\text{W}/\text{m}^2$, but this varies between the CMP series models. See section Technical data [▶ 25]

To accurately measure changes in irradiance of 1 W/m^2 the data logger or data acquisition system requires a total input measurement uncertainty (error) of 5 μV , or less; including noise, offsets, resolution, temperature effect, etc. The maximum irradiance under natural sunlight is unlikely to exceed 1500 W/m^2 .

- ▶ Connect the signal output to a single-ended or differential measurement system input.
- ▶ Ensure that the input impedance of the readout equipment is below 1 $\text{G}\Omega$.

i The output signal can be negative at night-time. This is normal and is not a fault.

7.3.4 Temperature signal output

The CMP10x has an internal temperature sensor close to the cold junction of the thermopile sensing element. Recording the sensor signal allows post-processing of the radiation data. The small effect of temperature changes that are not compensated by the internal circuit can be removed. The individual temperature response of each CMP10x is provided with the calibration certificate.

8 Operation

8.1 Making and saving measurements

The CMP series pyranometers only require a suitable source of radiation (light) to operate and make measurements, no power is required.

- ▶ To save the measurements, connect the pyranometer to a readout or data storage device. The pyranometer has no internal data memory.

8.2 Collecting data

An optimal setting for the data interval is to sample every second and store one minute averages.

- ▶ For setting up the combination of pyranometer and data storage read the manual of the data collection device.
- ▶ Take care to match the output range of the pyranometer to the input range of the data collection device to maximise the available resolution and minimise noise.
- ▶ To do this, determine the maximum analog output of the pyranometer and the minimum input range of the data collection device. See section Radiation signal output [▶ 18]

9 Maintenance

9.1 Maintenance schedule

The frequency of cleaning is dependent upon the local weather and environmental conditions. Ideally, the dome of the instrument should be cleaned every morning before sunrise. The frequency of cleaning can be reduced by the use of a ventilation unit, with the heaters switched on when necessary.

The following maintenance intervals are recommended:

| Interval | Activity | Performed by |
|--------------|--|--------------|
| Twice a week | <ul style="list-style-type: none"> ▶ Clean the dome using a dry and lint-free cloth. ▶ For persistent soiling, use additional distilled water. If the soiling is severe, pure alcohol can be used. ▶ Ensure that no streaks or deposits are left on the dome. | Operator |
| Monthly | <ul style="list-style-type: none"> ▶ Check that the instrument is standing horizontally or at the correct angle. Adjust the instrument if required. ▶ Check that the sun shield is fixed tightly. | Operator |
| Annually | <ul style="list-style-type: none"> ▶ Check all electrical connections: Unscrew the plugs, clean the plugs if necessary and reconnect. ▶ Check all cables for damage. ▶ Check fastenings and basic supports. ▶ Clean the sun shield if dirty. | Operator |
| 2 years | <ul style="list-style-type: none"> ▶ Check sensitivity or have a recalibration performed. | OTT HydroMet |
| 10 years | <ul style="list-style-type: none"> ▶ Replace the desiccant. | OTT HydroMet |

9.2 Replacing desiccant

The CMP10x pyranometer has an internal desiccant that needs replacement after 10 years. This is done with every factory re-calibration.

| Interval | Activity | Performed by |
|----------|---|--------------|
| 2 years | <ul style="list-style-type: none"> ▶ Perform recalibration to be IEC61724 Class A compliant. | OTT HydroMet |
| 5 years | <ul style="list-style-type: none"> ▶ Have a recalibration performed. | OTT HydroMet |

10 Troubleshooting

10.1 Fault elimination

| Fault | Possible cause | Measures |
|--|------------------------------------|--|
| Output signal not available or incorrect | Pyranometer does not work properly | <ul style="list-style-type: none">▶ Check that the cables are correctly connected to the readout equipment.▶ Check the location for obstacles that block the direct solar radiation.▶ Check the glass dome for contamination. Carry out maintenance work as required.▶ Check the data logger or readout offset by connecting a dummy load (100 Ohm resistor).<ul style="list-style-type: none">⇒ Gives a 'zero' reading.▶ Check that the leveling is correct.▶ Report any malfunctions or damage to the representative of OTT HydroMet. |

11 Repair

11.1 Customer support

- ▶ Have repairs carried out by OTT HydroMet service personnel.
- ▶ Only carry out repairs yourself, if you have first consulted OTT HydroMet.
- ▶ Contact your local representative: www.otthydromet.com/en/contact-us
- ▶ Include the following information:
 - instrument model
 - instrument serial number
 - details of the fault or problem
 - examples of data files
 - readout device or data acquisition system
 - interfaces and power supplies
 - history of any previous repairs or modifications
 - pictures of the installation
 - overview of the local environment conditions

12 Notes on disposing of old devices

Member States of the European Union

In accordance with the German Electrical and Electronic Equipment Act (ElektroG; national implementation of EU Directive 2012/19/EU), OTT HydroMet takes back old devices in the Member States of the European Union and disposes of them in the proper manner. The devices that this concerns are labeled with the following symbol:



- ▶ For further information on the take-back procedure contact OTT HydroMet:

OTT HydroMet B.V.

Service & Technical Support

Delftechpark 36

2628 XH Delft

The Netherlands

phone: +31 15 2755 210

email: solar-info@otthydromet.com

All other countries

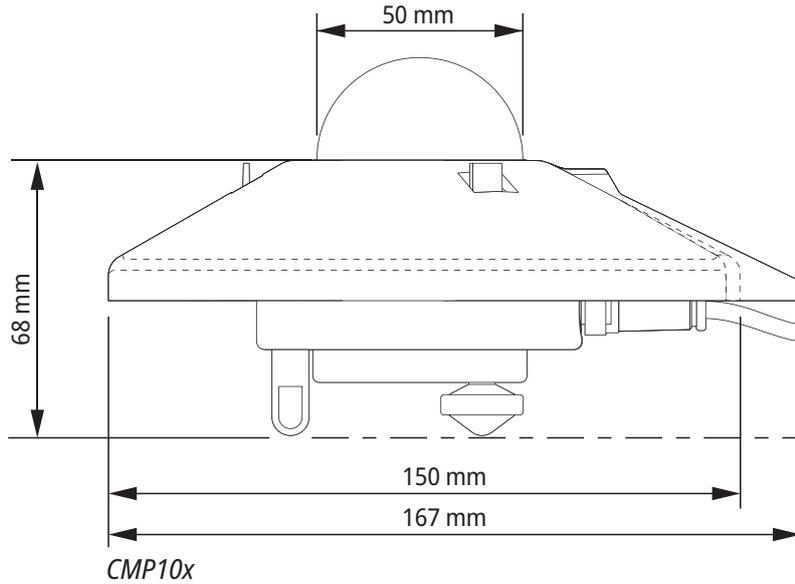
- ▶ Dispose of the product in the proper manner following decommissioning.
- ▶ Observe the country-specific regulations on disposing of electronic equipment.
- ▶ Do NOT dispose of the product in household waste.

13 Technical data

13.1 Optical and electrical data

| Specification | CMP10x |
|---|--|
| Classification to ISO 9060:2018 | Spectrally Flat Class A |
| Spectral range (20 % points) | 270 to 3000 nm |
| Spectral range (50 % points) | 285 to 2800 nm |
| Sensitivity | 7 to 16 $\mu\text{V}/\text{W}/\text{m}^2$ |
| Impedance | 10 to 100 Ω |
| Expected output range (0 to 1500 W/m^2) | 0 to 24 mV |
| Maximum operational irradiance | 2000 W/m^2 |
| Response time (63 %) | < 1.67 s |
| Response time (95 %) | < 5 s |
| Zero offset: | |
| a) thermal radiation (at -200 W/m^2) | < $\pm 7 \text{ W}/\text{m}^2$ |
| b) temperature change (5 K/h) | < $\pm 2 \text{ W}/\text{m}^2$ |
| c) total zero offset (a, b and other sources) | < $\pm 9 \text{ W}/\text{m}^2$ |
| Non-stability (change/year) | < $\pm 0.5 \%$ (per 5 years) |
| Non-linearity (100 to 1000 W/m^2) | < 0.2 % |
| Directional response (up to 80° with 1000 W/m^2 beam) | < $\pm 10 \text{ W}/\text{m}^2$ |
| Spectral selectivity (350 to 1500 nm) | < 3 % |
| Temperature response | < $\pm 1 \%$ (-10 °C to +40 °C) < $\pm 2 \%$ (-20 °C to +50 °C) |
| Tilt response (0° to 180° at 1000 W/m^2) | < 0.2 % |
| Spectral error | < 0.1 % |
| Field of view | 180° |
| Accuracy of bubble level | < 0.1° |
| Temperature sensor output | 10K Thermistor |
| Detector type | Thermopile |
| Operating temperature range | -40 °C to +80 °C |
| Storage temperature range | -40 °C to +80 °C |
| Humidity range (non-condensing) | 0 to 100 % RH |
| Ingress Protection (IP) rating | 67 |
| Recommended applications | Meteorological networks, PV panel and thermal collector testing, materials testing |

13.2 Dimensions and weight



| Specification | CMP10x |
|---|-----------------|
| Instrument weight | 500 g |
| Dimensions unpacked (diameter x height) | 15 x 9.25 cm |
| Packaging dimensions | 23 x 20 x 16 cm |
| Weight of 10 m cable | 400 g |

13.3 Resistance versus temperature

YSI Thermistor 44031

Thermistor (10 kΩ @ 25 °C)

$$T = (a + [b * (\ln (R)) + c * (\ln (R))^3])^{-1} - 273.15$$

| | | | |
|---|-------------------|---|-------------------|
| T | Temperature [°C] | b | $2.391 * 10^{-4}$ |
| R | Resistance [Ohm] | c | $1.568 * 10^{-7}$ |
| a | $1.095 * 10^{-3}$ | | |

| Temperature | | Resistance | Temperature | | Resistance | Temperature | | Resistance |
|-------------|-------|------------|-------------|------|------------|-------------|------|------------|
| [°C] | [°F] | [Ohm] | [°C] | [°F] | [Ohm] | [°C] | [°F] | [Ohm] |
| -30 | -22.0 | 135.200 | 0 | 32.0 | 29.490 | 30 | 86.0 | 8.194 |
| -29 | -20.2 | 127.900 | 1 | 33.8 | 28.150 | 31 | 87.8 | 7.880 |
| -28 | -18.4 | 121.100 | 2 | 35.6 | 26.890 | 32 | 89.6 | 7.579 |
| -27 | -16.6 | 114.600 | 3 | 37.4 | 25.690 | 33 | 91.4 | 7.291 |
| -26 | -14.8 | 108.600 | 4 | 39.2 | 24.550 | 34 | 93.2 | 7.016 |
| -25 | -13.0 | 102.900 | 5 | 41.0 | 23.460 | 35 | 95.0 | 6.752 |
| -24 | -11.2 | 97.490 | 6 | 42.8 | 22.430 | 36 | 96.8 | 6.500 |

| Temperature | | Resistance | Temperature | | Resistance | Temperature | | Resistance |
|-------------|------|------------|-------------|------|------------|-------------|-------|------------|
| [°C] | [°F] | [Ohm] | [°C] | [°F] | [Ohm] | [°C] | [°F] | [Ohm] |
| -23 | -9.4 | 92.430 | 7 | 44.6 | 21.450 | 37 | 98.6 | 6.258 |
| -22 | -7.6 | 87.660 | 8 | 46.4 | 20.520 | 38 | 100.4 | 6.026 |
| -21 | -5.8 | 83.160 | 9 | 48.2 | 19.630 | 39 | 102.2 | 5.805 |
| -20 | -4.0 | 78.910 | 10 | 50.0 | 18.790 | 40 | 104.0 | 5.592 |
| -19 | -2.2 | 74.910 | 11 | 51.8 | 17.980 | 41 | 105.8 | 5.389 |
| -18 | -0.4 | 71.130 | 12 | 53.6 | 17.220 | 42 | 107.6 | 5.193 |
| -17 | 1.4 | 67.570 | 13 | 55.4 | 16.490 | 43 | 109.4 | 5.006 |
| -16 | 3.2 | 64.200 | 14 | 57.2 | 15.790 | 44 | 111.2 | 4.827 |
| -15 | 5.0 | 61.020 | 15 | 59.0 | 15.130 | 45 | 113.0 | 4.655 |
| -14 | 6.8 | 58.010 | 16 | 60.8 | 14.500 | 46 | 114.8 | 4.489 |
| -13 | 8.6 | 55.170 | 17 | 62.6 | 13.900 | 47 | 116.6 | 4.331 |
| -12 | 10.4 | 52.480 | 18 | 64.4 | 13.330 | 48 | 118.4 | 4.179 |
| -11 | 12.2 | 49.940 | 19 | 66.2 | 12.790 | 49 | 120.2 | 4.033 |
| -10 | 14.0 | 47.540 | 20 | 68.0 | 12.260 | 50 | 122.0 | 3.893 |
| -9 | 15.8 | 45.270 | 21 | 69.8 | 11.770 | 51 | 123.8 | 3.758 |
| -8 | 17.6 | 43.110 | 22 | 71.6 | 11.290 | 52 | 125.6 | 3.629 |
| -7 | 19.4 | 41.070 | 23 | 73.4 | 10.840 | 53 | 127.4 | 3.504 |
| -6 | 21.2 | 39.140 | 24 | 75.2 | 10.410 | 54 | 129.2 | 3.385 |
| -5 | 23.0 | 37.310 | 25 | 77.0 | 10.000 | 55 | 131.0 | 3.270 |
| -4 | 24.8 | 35.570 | 26 | 78.8 | 9.605 | 56 | 132.8 | 3.160 |
| -3 | 26.6 | 33.930 | 27 | 80.6 | 9.227 | 57 | 134.6 | 3.054 |
| -2 | 28.4 | 32.370 | 28 | 82.4 | 8.867 | 58 | 136.4 | 2.952 |
| -1 | 30.2 | 30.890 | 29 | 84.2 | 8.523 | 59 | 138.2 | 2.854 |



Contact Information

