

9.7 Appendix on ISO and WMO classification tables

Table 9.7.1 Classification table for pyranometers per ISO 9060 and WMO.

NOTE: WMO specification of spectral selectivity is different from that of ISO. Hukseflux conforms to the ISO limits. WMO also specifies expected accuracies. ISO finds this not to be a part of the classification system because it also involves calibration. Please note that WMO achievable accuracies are for clear days at mid latitudes and that the uncertainty estimate does not include uncertainty due to calibration*.

ISO CLASSIFICATION** TABLE			
ISO CLASS	SECONDARY STANDARD	FIRST CLASS	SECOND CLASS
Specification limit			
Response time (95 %)	15 s	30 s	60 s
Zero offset a (response to 200 W/m ² net thermal radiation)	+ 7 W/m ²	+ 15 W/m ²	+ 30 W/m ²
Zero offset b (response to 5 K/h in ambient temperature)	± 2 W/m ²	± 4 W/m ²	± 8 W/m ²
Non-stability (change per year)	± 0.8 %	± 1.5 %	± 3 %
Non-linearity (100 to 1000 W/m ²)	± 0.5 %	± 1 %	± 3 %
Directional response	± 10 W/m ²	± 20 W/m ²	± 30 W/m ²
Spectral selectivity (350 to 1 500 x 10 ⁻⁹ m) (WMO 300 to 3 000 x 10 ⁻⁹ m)	± 3 %	± 5 %	± 10 %
Temperature response (interval of 50 K)**	2 %	4 %	8 %
Tilt response (0 to 90 ° at 1000 W/m ²)	± 0.5 %	± 2 %	± 5 %
ADDITIONAL WMO SPECIFICATIONS			
WMO CLASS	HIGH QUALITY	GOOD QUALITY	MODERATE QUALITY
WMO: achievable accuracy for daily sums*	2 %	5 %	10 %
WMO: achievable accuracy for hourly sums*	3 %	8 %	20 %
WMO: achievable accuracy for minute sums*	not specified	not specified	not specified
WMO: resolution (smallest detectable change)	1 W/m ²	5 W/m ²	10 W/m ²
CONFORMITY TESTING***			
ISO 9060	individual instrument only: all specs must comply	group compliance	group compliance

* WMO 7.2.1: The estimated uncertainties are based on the following assumptions: (a) instruments are well-maintained, correctly aligned and clean; (b) 1 min and 1 h figures are for clear-sky irradiances at solar noon; (c) daily exposure values are for clear days at mid-latitudes. WMO 7.3.2.5: Table 7.5 lists the expected maximum deviation from the true value, excluding calibration errors.

** At Hukseflux the expression ± 1 % is used instead of a range of 2 %.

*** an instrument is subject to conformity testing of its specifications. Depending on the classification, conformity compliance can be proven either by group- or individual compliance. A specification is fulfilled if the mean value of the respective test result does not exceed the corresponding limiting value of the specification for the specific category of instrument.

9.8 Appendix on definition of pyranometer specifications

Table 9.8.1 Definition of pyranometer specifications

SPECIFICATION	DEFINITION	SOURCE
Response time (95 %)	time for 95 % response. The time interval between the instant when a stimulus is subjected to a specified abrupt change and the instant when the response reaches and remains within specified limits around its final steady value. The response time is a measure of the thermal inertia inherent in the stabilization period for a final reading.	ISO 9060-1990 WMO 1.6.3
Zero offset a: (200 W/m ² net thermal radiation)	response to 200 W/m ² net thermal radiation (ventilated). Hukseflux assumes that unventilated instruments have to specify the zero-offset in unventilated – worst case – conditions. Zero offsets are a measure of the stability of the zero-point. Zero offset a is visible at night as a negative offset, the instrument dome irradiates in the far infra red to the relatively cold sky. This causes the dome to cool down. The pyranometer sensor irradiates to the relatively cool dome, causing a negative offset. Zero offset a is also assumed to be present during daytime.	ISO 9060-1990
Zero offset b: (5 K/h in ambient temperature)	response to 5 K/h change in ambient temperature. Zero offsets are a measure of the stability of the zero-point.	ISO 9060-1990
Non-stability (change per year)	percentage change in sensitivity per year. The dependence of sensitivity resulting from ageing effects which is a measure of the long-term stability.	ISO 9060-1990
Non-linearity (100 to 1000 W/m ²)	percentage deviation from the sensitivity at 500 W/m ² due to the change in irradiance within the range of 100 W/m ² to 1000 W/m ² . Non-linearity has an overlap with directional response, and therefore should be handled with care in uncertainty evaluation.	ISO 9060-1990
Directional response	the range of errors caused by assuming that the normal incidence sensitivity is valid for all directions when measuring from any direction a beam radiation whose normal incidence irradiance is 1000 W/m ² . Directional response is a measure of the deviations from the ideal "cosine behaviour" and its azimuthal variation.	ISO 9060-1990
Spectral selectivity (350 to 1500 x 10 ⁻⁹ m) (WMO 300 to 3000 x 10 ⁻⁹ m)	percentage deviation of the product of spectral absorptance and spectral transmittance from the corresponding mean within 350 x 10 ⁻⁹ m to 1500 x 10 ⁻⁹ m and the spectral distribution of irradiance. Spectral selectivity is a measure of the spectral selectivity of the sensitivity.	ISO 9060-1990
Temperature response (interval of 50 K)	percentage deviation of the sensitivity due to change in ambient temperature within an interval of 50 K the temperature of the pyranometer body.	ISO 9060-1990
Tilt response (0° to 90° at 1000 W/m ²)	percentage deviation from the sensitivity at 0° tilt (horizontal) due to change in tilt from 0° to 90° at 1000 W/m ² irradiance. Tilt response describes changes of the sensitivity due to changes of the tilt angle of the receiving surface.	ISO 9060-1990
Sensitivity	the change in the response of a measuring instrument divided by the corresponding change in the stimulus.	WMO 1.6.3
Spectral range	the spectral range of radiation to which the instrument is sensitive. For a normal pyranometer this should be in the 0.3 to 3 x 10 ⁻⁶ m range. Some pyranometers with coloured glass domes have a limited spectral range.	Hukseflux

9.9 Appendix on terminology / glossary

Table 9.9.1 Definitions and references of used terms

TERM	DEFINITION (REFERENCE)
Solar energy or solar radiation	solar energy is the electromagnetic energy emitted by the sun. Solar energy is also called solar radiation and shortwave radiation. The solar radiation incident on the top of the terrestrial atmosphere is called extra-terrestrial solar radiation; 97 % of which is confined to the spectral range of 290 to $3\,000 \times 10^{-9}$ m. Part of the extra-terrestrial solar radiation penetrates the atmosphere and directly reaches the earth's surface, while part of it is scattered and / or absorbed by the gas molecules, aerosol particles, cloud droplets and cloud crystals in the atmosphere. The former is the direct component, the latter is the diffuse component of the solar radiation. (ref: WMO, Hukseflux)
Hemispherical solar radiation	solar radiation received by a plane surface from a 180° field of view angle (solid angle of 2π sr).(ref: ISO 9060)
Global solar radiation	the solar radiation received from a 180° field of view angle on a horizontal surface is referred to as global radiation. Also called GHI. This includes radiation received directly from the solid angle of the sun's disc, as well as diffuse sky radiation that has been scattered in traversing the atmosphere. (ref: WMO) Hemispherical solar radiation received by a horizontal plane surface. (ref: ISO 9060)
Plane-of-array irradiance	also POA: hemispherical solar irradiance in the plane of a PV array. (ref: ASTM E2848-11 / IEC 61724)
Direct solar radiation	radiation received from a small solid angle centred on the sun's disc, on a given plane. (ref: ISO 9060)
Terrestrial or Longwave radiation	radiation not of solar origin but of terrestrial and atmospheric origin and having longer wavelengths ($3\,000$ to $100\,000 \times 10^{-9}$ m). In case of downwelling $E_i \downarrow$ also the background radiation from the universe is involved, passing through the "atmospheric window". In case of upwelling $E_i \uparrow$, composed of long-wave electromagnetic energy emitted by the earth's surface and by the gases, aerosols and clouds of the atmosphere; it is also partly absorbed within the atmosphere. For a temperature of 300 K, 99.99 % of the power of the terrestrial radiation has a wavelength longer than $3\,000 \times 10^{-9}$ m and about 99 per cent longer than $5\,000 \times 10^{-9}$ m. For lower temperatures, the spectrum shifts to longer wavelengths. (ref: WMO)
World Radiometric Reference (WRR)	measurement standard representing the SI unit of irradiance with an uncertainty of less than ± 0.3 % (see the WMO Guide to Meteorological Instruments and Methods of Observation, 1983, subclause 9.1.3). The reference was adopted by the World Meteorological Organization (WMO) and has been in effect since 1 July 1980. (ref: ISO 9060)
Albedo	ratio of reflected and incoming solar radiation. Dimensionless number that varies between 0 and 1. Typical albedo values are: < 0.1 for water, from 0.1 for wet soils to 0.5 for dry sand, from 0.1 to 0.4 for vegetation, up to 0.9 for fresh snow.
Angle of incidence	angle of radiation relative to the sensor measured from normal incidence (varies from 0° to 90°).
Zenith angle	angle of incidence of radiation, relative to zenith. Equals angle of incidence for horizontally mounted instruments
Azimuth angle	angle of incidence of radiation, projected in the plane of the sensor surface. Varies from 0° to 360° . 0 is by definition the cable exit direction, also called north, east is $+90^\circ$. (ASTM G113-09)
Sunshine duration	sunshine duration during a given period is defined as the sum of that sub-period for which the direct solar irradiance exceeds 120 W/m^2 . (ref: WMO)