ISO 9060 pyranometer classification

How the ISO 9060 standard impacts solar radiation measurement in PV monitoring and meteorological applications

Pyranometers are reference sensors for measuring solar radiation and are used in PV system performance monitoring and meteorology. ISO 9060, which was revised in 2018, is the globally recognised standard that defines pyranometer classification. It distinguishes three accuracy classes: Class A, B, and C. The measurement uncertainty approximately decreases by a factor of 2 from Class C to B and Class B to A. A pyranometers belongs to a certain Class if all specification and classification criteria are met. Furthermore, ISO 9060 defines the additional properties “spectrally flat” and “fast response”. It is important to note that pyranometer selection should not only rely on ISO Class, since there are significant differences in attained measurement accuracy even within a Class.

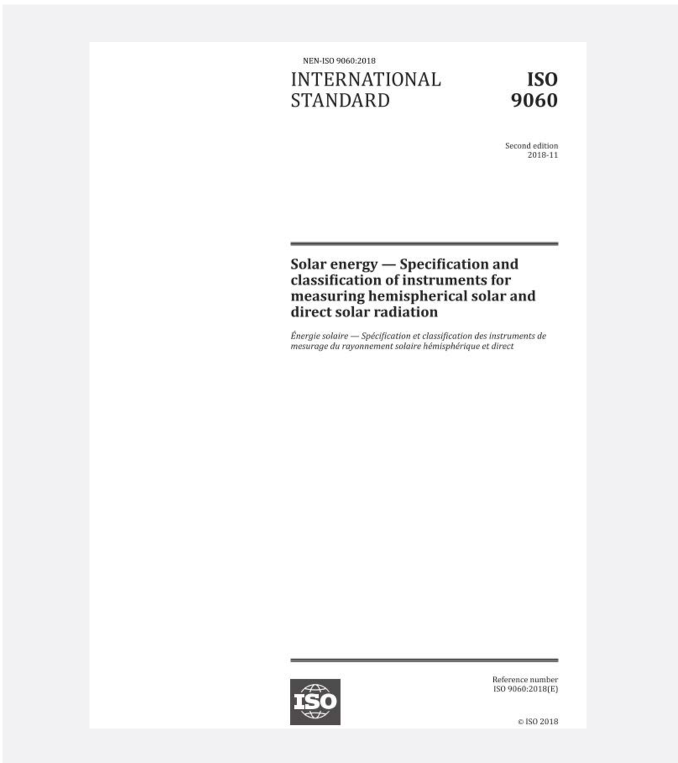
This note also highlights best practices from ASTM G213-17 and ISO/TR 9901 for estimating and minimizing measurement uncertainty to ensure reliable solar irradiance data. In addition, the IEC 61724-1 standard for PV system performance monitoring explicitly requires the use of ISO 9060-compliant pyranometers.

Introduction

ISO 9060: Solar energy—Specification and classification of instruments for measuring hemispherical solar and direct solar irradiance—is the globally recognized standard that defines pyranometer specification and classification. The first version of the standard dates back to 1990. In 2018, a major revision was made. This revision was not only an update in terminology, but it also raised the bar for compliance to an accuracy class.

Pyranometer classification

Pyranometers are classified according to ISO 9060 in 3 accuracy classes: Class A, Class B, and Class C. A pyranometer belongs to a specific class if all specifications of the respective class and all classification criteria are unambiguously met. Table 1 summarizes the specification criteria for compliance to an accuracy class. For detailed definitions of the parameters, please refer to the standard. A short explanation of the parameters is given below: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ISO 9060
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Solar energy — Specification and classification of instruments for measuring hemispherical solar and direct solar radiation

Énergie solaire — Spécification et classification des instruments de mesurage du rayonnement solaire hémisphérique et direct

Reference number ISO 9060:2018(E)

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Figure 1 Cover of the 2018 version of the ISO 9060 standard.

- Response time (95 %): the time interval after a step change in light until the pyranometer signal reaches and remains within 95 % of its final value.
- Zero offset a: response to -200 W/m² net thermal radiation.
- Zero offset b: response to 5 K/h change in ambient temperature.
- Zero offset c: total zero offset, including the effects of zero offset a, zero offset b, and other sources.
- Non-stability: percentage change in responsivity per year.
- Nonlinearity: percentage change in responsivity per year.
- Directional response: the range of errors caused by assuming that the normal incidence responsivity is valid for all directions when measuring from any direction (with an incidence angle of up to 90 ° or even from below the sensor) a beam radiation whose normal incidence irradiance is 1 000 W/m².
- Clear sky global horizontal irradiance spectral error: maximum spectral error observed for a set of global horizontal irradiance clear sky spectra defined in ISO 9060.
- Temperature response: percentage deviation due to change in ambient temperature within the interval from -10 °C to 40 °C relative to the signal at 20 °C.
- Tilt response: percentage deviation from the responsivity at 0 ° tilt (horizontal) due to change in tilt from 0 ° to 180 ° at 1 000 W/m² irradiance.

Table 1 Pyranometer specification criteria according to ISO 9060:2018. Individual parameters are explained in the main text. The listed values represent acceptance intervals for each parameter. For accompanying guard bands, see the standard.

PYRANOMETER SPECIFICATION ACCORDING TO ISO 9060:2018

	Class A (previously secondary standard)	**Class B (previously first class)**	**Class C (previously second class)**	**Hukx SR300, SR200 (Class A)**
response time (95 %)	< 10 s	< 20 s	< 30 s	3 s
zero offset a	± 7 W/m²	± 15 W/m²	± 30 W/m²	< ± 2 W/m² (SR300) < ± 5 W/m² (SR200)
zero offset b	± 2 W/m²	± 4 W/m²	± 8 W/m²	< ± 2 W/m²
zero offset c	± 10 W/m²	± 21 W/m²	± 41 W/m²	< 5 W/m²
non-stability	± 0.8 %	± 1.5 %	± 3 %	< ± 0.5 % / yr
nonlinearity	± 0.5 %	± 1 %	± 3 %	< 0.2 %
directional response	± 10 W/m²	± 20 W/m²	± 30 W/m²	< ± 10 W/m²
clear sky GHI spectral error	± 0.5 %	± 1 %	± 5 %	< ± 0.5 %
temperature response	± 1 %	± 2 %	± 4 %	< ± 0.4 %
tilt response	± 0.5 %	± 2 %	± 5 %	< ± 0.2 %
additional signal processing errors	± 2 W/m²	± 5 W/m²	± 10 W/m²	none (signal processing errors are included in other specifications)

Changes in the 2018 revision

Here are the key changes to the standard in the 2018 revision compared to the 1990 version. The 2018 version of ISO 9060 includes:

- 3 instrument accuracy Classes: A, B and C (previously secondary standard, first class and second class).
- a special addition to every Class: "spectrally flat". This addition applies to sensors that respond equally to all wavelengths of incoming sunlight and is recommended for Plane of Array, albedo, and Rear-side Plane of Array measurements. For the addition "spectrally flat", it is required that the spectral selectivity (the percentage deviation of the spectral responsivity from the corresponding mean within the range 0,35 μm and 1,5 μm) is lower than 3 %.
- a special addition to every Class: "fast response". This addition applies to pyranometers that have a low response time and is recommended when measuring highly variable data such as over-irradiance events[NR1.1]. For the addition "fast response", the sensor's response time needs to be below 0.5 s.
- a new parameter for pyranometer class assessment: spectral error (in contrast to the previous assessment parameter: spectral selectivity).
- a requirement for individual testing of both temperature response and directional response for Class A pyranometers.

Limits and guard bands

ISO 9060:2018 specifies the numbers in Table 1 as *acceptance limits* for each listed parameter. These limits are deliberately chosen narrower than the corresponding *tolerance limits* (the ranges within which the device under test is expected to perform) to account for measurement uncertainty and to reduce the risk of a false decision. The gap between the tolerance limit and acceptance limit is known as the *guard band*. ISO 9060:2018 defines such guard bands for all properties included in Table 1 of the standard. Guard bands are not included in this note.

What is an accuracy class?

ISO 9060 defines three accuracy classes for pyranometers: Class A, Class B and Class C. The concept of an accuracy class is defined by the International Vocabulary of Metrology (VIM), paragraph 4.25, as "class of measuring instruments or measuring systems that meet stated metrological requirements that are intended to keep measurement errors or instrumental uncertainties within specified limits under specified operating conditions".
Compliance with an accuracy class is sufficient to claim a certain measurement uncertainty by comparison to other systems of the same class according to the Guide to the Expression of Uncertainty in Measurement (GUM), type B evaluation of uncertainty, see also VIM paragraph 2.29.

Pyranometer accuracy

From Class C to Class B and from Class B to Class A, the measurement uncertainty of pyranometers approximately decreases by a factor of 2. See Figure 2 for an impression of measurement accuracy for the different pyranometer classes.

A general rule: the higher the required accuracy:
- the higher the cost of the instrument
- the higher the required level of maintenance (cleaning)
- the higher the required accuracy of calibration

In many cases the specifications of Hukx pyranometers are much better than the Class requires (see Table 1). This than results in better measurement accuracy than estimated just based on the classification. Table 2 shows an overview of Hukx pyranometers and their classification.

Table 2 Hukx pyranometers and their ISO 9060:2018 class and IEC 61724 1:2021 compliance.

Brand	Model	ISO 9060:2018 Class	IEC 61724-1:2021 Compliance
Hukx	SR30, SR300	Class A	Class A for all locations and conditions
Hukx	SR20, SR200	Class A	Class A only for locations where dew and frost are expected less than 2 % of the time

Hukx	SR100	Class B	Class A for rear-side plane of array irradiance Class B for other irradiance measurements
Hukx	SR05	Class C	Class A for rear-side plane of array irradiance Class B for other irradiance measurements

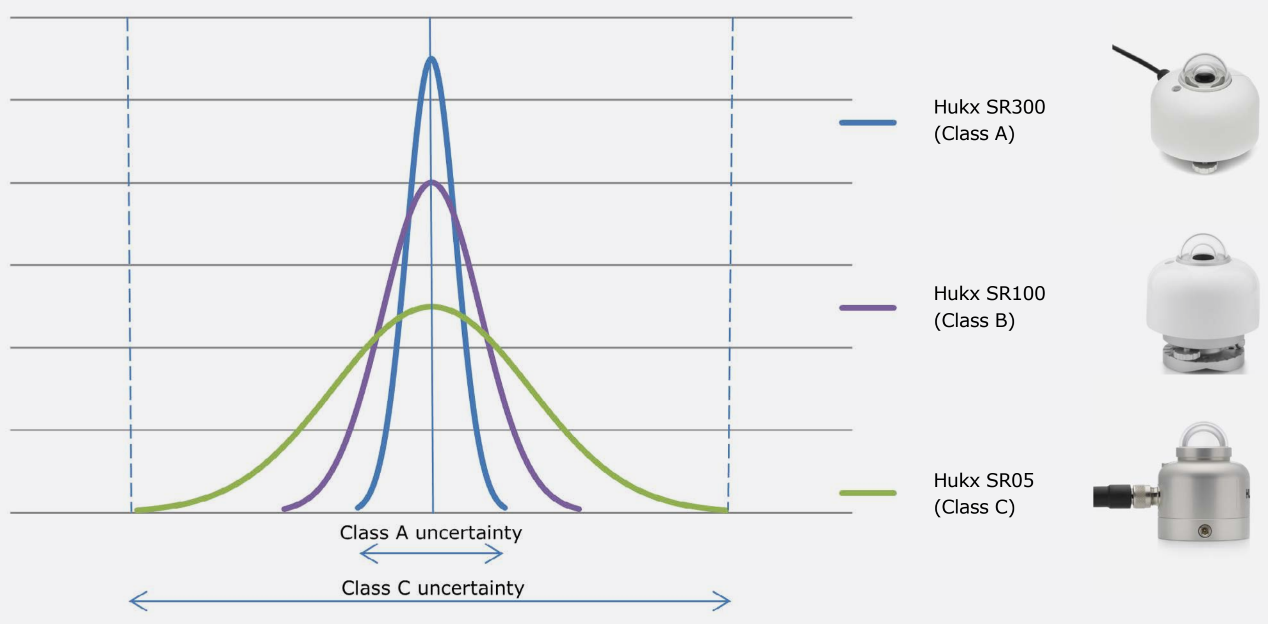

Figure 2 Illustration of the measurement uncertainty associated with different ISO 9060:2018 pyranometer classes. The bell curves represent the probability distribution of measurement errors: wider curves indicate larger uncertainty, while narrower curves indicate smaller uncertainty. From Class C to Class B and from Class B to Class A, the uncertainty is reduced by roughly a factor of two for well-maintained instruments.

Why you need a "spectrally flat" pyranometer in PV monitoring and in meteorology

Spectrally flat pyranometers have a uniform sensitivity across the solar wavelength range, ensuring that all parts of the spectrum contribute equally to the measured irradiance. Because their response does not depend on the spectral composition of the incident light, they deliver accurate data under all atmospheric conditions. This makes them the preferred choice for PV monitoring and meteorological applications. At Hukx, we therefore only supply spectrally flat pyranometers.

The ISO 9060 standard specifically states the importance of "spectrally flat" instruments for the measurement of reflected solar radiation and albedo. In these applications, the spectral composition of the reflected light can differ strongly from direct sunlight, making a spectrally flat response even more critical for reliable results. Additionally, spectrally flat measurements are essential for Plane of Array (including reflected) irradiance.

Pyranometer selection

While ISO Class is an important criterion when selecting a pyranometer, it should not be the only one. Even within the same Class, pyranometers can differ greatly in measurement accuracy. For example, this application note presents independent data from the National Renewable Energy Laboratory (NREL), showing that the Hukx SR30 outperforms its main competitors in directional response. Since the directional response is the largest contributor to the total uncertainty, the observed difference strongly affects the total measurement accuracy.

Best practices

ISO/TR 9901: *Solar energy—Pyranometers—Recommended practice for use*—gives recommended practices for pyranometer operation, calibration, and maintenance.

It provides guidance on instrument selection, installation, and quality assurance procedures to ensure reliable measurements. The report includes recommendations to minimize uncertainties in measurements of solar radiation, focusing on proper siting and alignment, regular maintenance, and calibration.

Uncertainty evaluation

The ASTM G213-17 provides guidance and recommended practices for evaluating uncertainties when performing outdoor measurements with pyranometers. The ASTM standard follows the ISO Guide 98 group, which includes the Guide to the Expression of Uncertainty in Measurement (GUM). Figure 4 shows the uncertainty evaluation of a pyranometer that just meets the Class A requirements of ISO 9060 (i.e., all specifications are at the acceptance limits visible in Table 1) and with a calibration uncertainty of 1.5 %. The evaluation is copied from ISO/TR 9901:2021 (section 5.6) and was originally performed with a spreadsheet adjunct to ASTM G213-17. Different colors indicate the contribution of different uncertainty sources to the total uncertainty. It is visible that the directional response is the biggest contributor to the total uncertainty for this case. This is true for almost all commercially available pyranometers.

What does IEC 61724-1 require?

Many PV monitoring systems comply with IEC 61724-1: *Photovoltaic system performance monitoring—Guidelines for measurement, data exchange and analysis*. This IEC standard is linked to ISO 9060: it requires compliance with the latest available version of the ISO 9060 standard. This means users claiming compliance with IEC 61724 1 "Class A monitoring systems" need to take special care. For example, for a Class A monitoring system, all front side (Plane of Array and horizontal) sensors need to be of ISO 9060 "spectrally flat" Class A. Rear-side sensors need to classify as ISO 9060 Class C or better. Also for IEC 61724 1 Class B monitoring systems, all irradiance sensors need to be ISO 9060 Class C or better.

Ordering the ISO 9060 standard

The ISO 9060 standard can be purchased from the ISO webstore.

Figure 3 Two SR300 spectrally flat Class A pyranometers measuring GHI (global horizontal irradiance) and POA (Plane of Array) in a PV performance monitoring system.

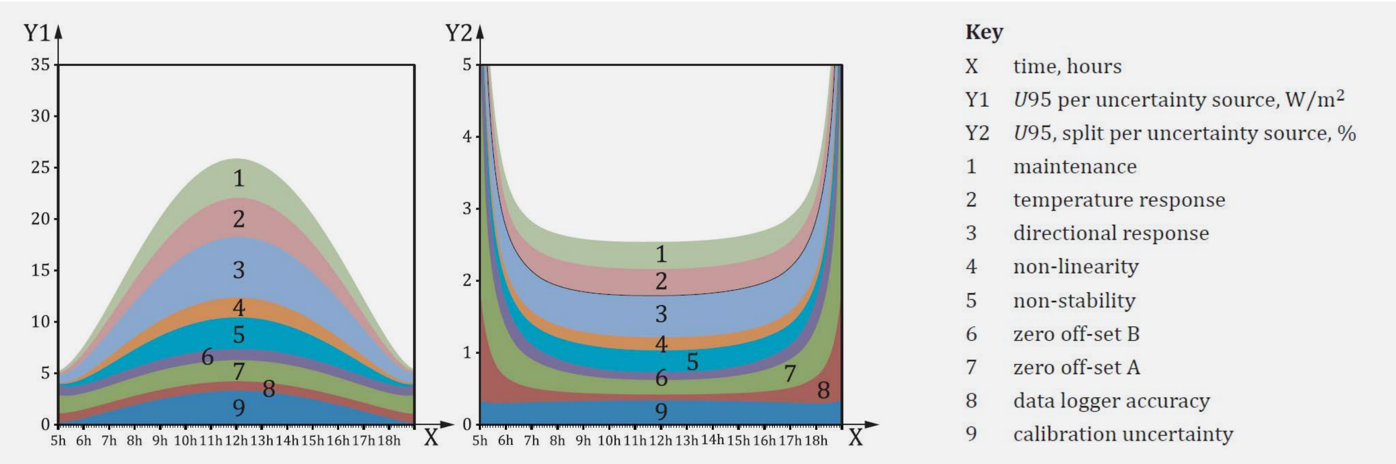

Figure 4 Extract from ISO/TR 9901:2021 (section 5.6), showing an example of the U95 uncertainties for global horizontal irradiance measurements with a spectrally flat Class A pyranometer on a clear sunny day, with 1 000 W/m² irradiance at solar noon. The different colors represent different uncertainty sources. The left plot shows the absolute uncertainty in W/m², whereas the right plot shows the relative uncertainty in percents.

About Hukx

Hukx is the leading innovator in solar radiation and heat flux sensor technology. We are proud to set the standard in high-accuracy measurement, and to be working at the heart of the energy transition.

Customers worldwide rely on our bestselling pyranometers and heat flux sensors. From sensor design and selection to supply and recalibration, we support you across the entire lifecycle.

Hukx is headquartered in the Netherlands, with locally owned representative sales offices in the USA, Brazil, India, China, Southeast Asia, and Japan.

Let us help you select the best sensor for your application.
Get in touch with our experts today via: info@hukx.com

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