ISO 9060:2018 A PRACTICAL AND SCIENTIFIC GUIDE

WHITE PAPER

OTT HydroMet

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To make the most of the sun’s radiation and ensure top performance of a solar installation, facility operators require equipment that takes precise measurements of various parameters. The best way to do that is to see if a site’s radiometers meet international standards — specifically, the ISO 9060. Created almost 30 years ago by the International Organization for Standardization, ISO 9060 details minimum performance parameters for equipment that measures global horizontal, tilted, diffuse horizontal and direct normal irradiance.

In 2018, it was updated for the first time, to catch up with a solar industry that has changed dramatically since 1990 when the guidelines were originally written. The new standards make it easier to forecast measurement errors and tolerance measurements, among other things. Understanding these updates, as well as the original, allows operators to better compare their experiences with global best practices and improve overall performance at their solar installations.

The major changes that operators should be aware of involve spectral performance. ISO 9060:2018 clarified key elements of the spectral response metric. Spectral response measures the way the instruments respond to light as a function of the wavelength of the light. Ideally, a solar energy pyranometer (also called a radiometer) should have a flat response over a wide spectral bandwidth to measure all available incoming solar energy, regardless of the types of photovoltaic modules or solar collectors used.

But to understand the 2018 changes, it’s vital to comprehend what came before and the terms referenced.

About the ISO

The International Organization for Standardization is an independent, nongovernmental organization that sets international standards to ensure products and services are compatible across markets. Often referred to as ISO, the group also identifies and addresses safety issues and shares best practices.

ISO 9060:1990

In the 1990 standard, **spectral selectivity** (the flat response) is defined as the deviation from the mean wavelength range of 350 nm to 1500 nm (0.35 μm to 1.5 μm). It's a function of the spectral absorptance of the black coating and the spectral transmittance of the dome/window and/or diffuser material and any optical filters that are fitted. Think of it as how much the response varies from the average response for a specific wavelength. It is typically described as a percentage.

Selectivity limits for pyranometers are classified in the 1990 standard as:

- **Secondary Standard:** ± 3% (There was no primary standard.)
- **First Class:** ± 5%
- **Second Class:** ± 10%

A primary standard was referenced for pyrheliometers, but not as a performance calculation.

To comply with this requirement, pyranometers usually have a thermoelectric type of detector with a black coating that absorbs incoming radiation, heats up a thermopile and converts the temperature rise into a small voltage. There are no production PV materials that significantly respond to photons of light of wavelength longer than 1500 nm, including multilayer thin-film technologies.

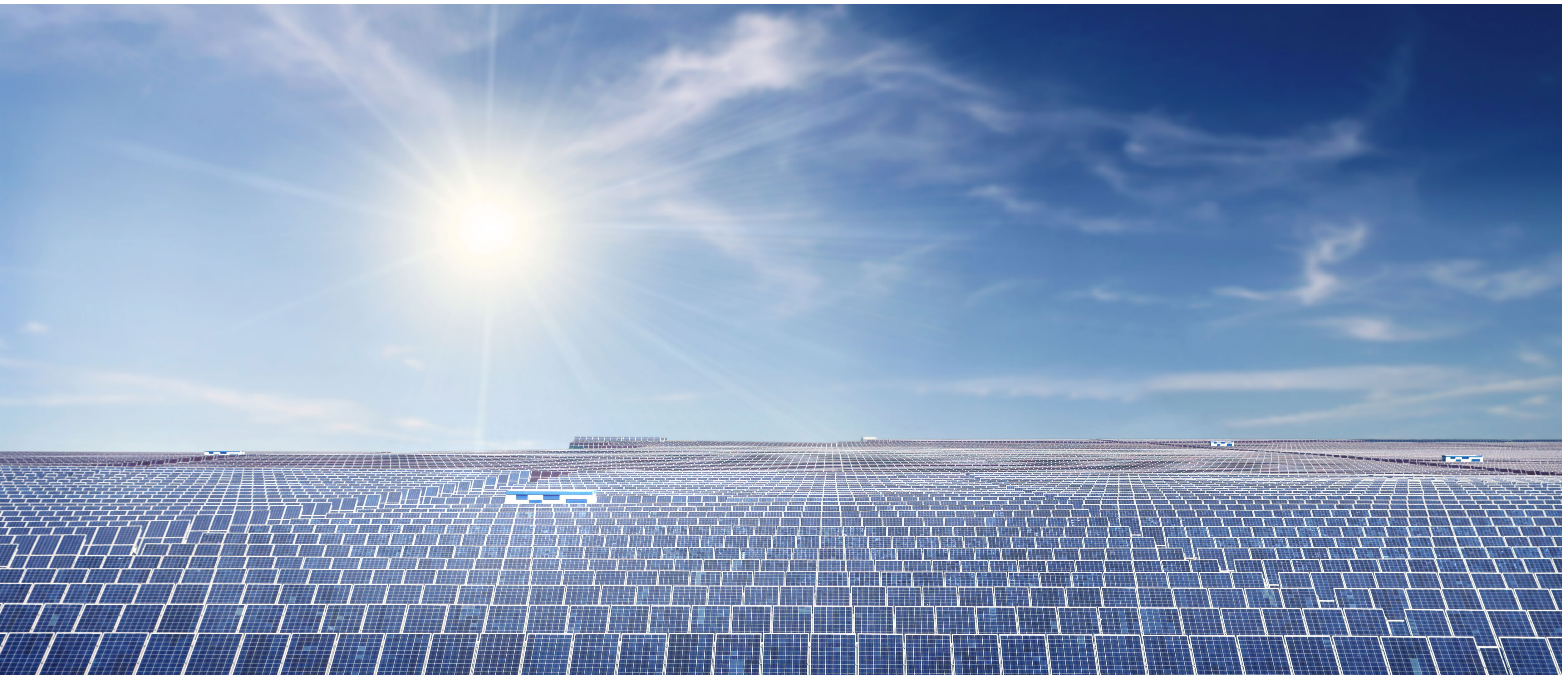
Photoelectric sensors, including silicon cells and photodiodes, have a limited and uneven spectral response that doesn't meet the ISO 9060:1990 spectral selectivity specifications for a pyranometer (or pyrheliometer) and must be described as a "silicon pyranometer" or something similar.

ISO 9060:2018

Late in 2018, the ISO announced changes to the ISO 9060. The goal was to better reflect the type of precise measurements required at contemporary solar installations. The 2018 standard makes for easier identification of field measurement errors related to spectral response, and allows silicon cell and photodiode sensors to meet lower performance classifications. The new version also redefines and clarifies important metrics and criteria, such as:

Spectral selectivity, now described as **clear sky irradiance spectral error** to provide a better estimate of field measurement errors that can be expected based on the spectral response of a radiometer under various conditions.

Spectral error, which arises in a pyranometer measurement under two different spectra. It is calculated by combining reference solar spectra for a number of sky and atmospheric conditions with the radiometer's measured spectral response. For example, spectra occurring at air mass 1.5 and air mass 5, at +/- 13:30 and +/- 18:00 respectively are dependent on factors such as the time, season and location.



Spectral flatness, which shows how constant (or flat) the instrument response is for different wavelengths. It indicates instruments with black absorbers and with or without diffusers that don't require additional data processing to yield good performance in multiple sky conditions.

Guard bands, which strengthen the 1990 selectivity limits to account for the uncertainty in determining an actual value. The bands represent the interval between a tolerance limit and a corresponding acceptance limit. The 2018 limit and guard bands for pyranometers are:

- **Class A:** ± 0.5% (0.1%), which is roughly equivalent to the 1990 Secondary Standard. Class A pyranometers must be individually tested to ensure their temperature and directional responses meet the requirements of the standard.
- **Class B:** ± 1% (0.5%), which is equivalent to the 1990 First Class.
- **Class C:** ± 5% (1%), which is equivalent to the 1990 Second Class.

A pyranometer with a spectral error rate of less than 3% (guard bands 2%) in the wavelength range from 350 nm to 1500 nm (0.35 μm to 1.5 μm) is considered "spectrally flat" and meets the ISO 9060:1990 Secondary Standard pyranometer criteria, which is stricter than both the 1990 First Class and Second Class pyranometers limits.

Instruments not addressed by ISO 9060:2018

Instruments with a limited spectral range that use or need corrections with air mass or cloud coverage are not included in the spectrally flat standard. The relative air mass (thickness of the atmosphere) changes with the solar zenith angle. When the sun is low in the sky, the direct beam comes through more atmosphere and the spectrum of the light changes.

Airmass = 1/Cos θ (Solar Zenith Angle)

Sun at Solar Zenith Angle of 0°: AM = 1

Sun at Solar Zenith Angle of 48.2°: AM = 1.5

The relationship breaks down beyond Solar Zenith Angle of 85°: AM = 11.4

The short wavelengths (ultraviolet and blue) are absorbed and scattered and the spectrum shifts toward the longer wavelengths (red and infrared). This also happens with cloud cover, increasing concentration of aerosols and particulates in the atmosphere and decreasing visibility.

Tools for Compliance

An understanding of the new ISO 9060:2018 guidelines empowers solar facility operators to choose radiometers that meet, if not exceed, these international standards, which can greatly improve a solar site's performance.

The spectral error on pyranometers carried by OTT HydroMet is much lower than the ISO 9060:2018 standard, making it a good choice for upgrades and a useful tool in modernizing a facility. CMP series and SMP series pyranometers and the CM4 high-temperature pyranometer have spectral selectivity of less than 3% and meet ISO 9060:2108 spectrally flat criteria.

The following are products that more than meet specific class criteria.

ISO 9060:2018	Class C	Spectrally Flat Class C	Spectrally Flat Class B	Spectrally Flat Class A
ISO 9060:1990	Not allowed	Second Class	First Class	Secondary Standard
Accuracy	Lowest accuracy	Higher accuracy than non-spectral flat C	Higher accuracy than any class C	Highest accuracy
Passive pyranometers	SP Lite2 (Fast Response)	CM4* CMP3	CMP6	CMP10 CMP11 CMP21 CMP22
Smart pyranometers	RT1	SMP3	SMP6	SMP10 SMP11 SMP21 SMP22

** The Kipp & Zonen CM4 High Temperature Pyranometer is a radiometer specially designed for measuring solar or artificial light irradiance under the most extreme temperature conditions. With an operating temperature range of -40 °C to +150 °C and measurement up to 4000 W/m² it is a unique product.*

Source: Kipp & Zonen
Note: ISO 9060:2018 Class A pyranometers must be individually tested to ensure that their temperature and directional responses meet the requirements of the standard.

> **“It is now understood that variances that might once have seemed minimal can actually have major effects on site efficiencies and returns on investment.”**

As the industry has matured, maximizing solar facility performance has become of paramount importance. It is now understood that variances that might once have seemed minimal can actually have major effects on site efficiencies and returns on investment. The key steps are to test the current equipment against ISO 9060:2018 guidelines and then consider upgrading poorly performing equipment.

Learn more

OTT HydroMet, with over a 140-year history, delivers valuable insights, quality instruments, and monitoring solutions that improve analysis and support decision-making for experts in hydromet and solar applications. Its subsidiaries and agencies in more than 90 countries supply the broadest portfolio of efficient solutions and services in hydrology, meteorology, and solar energy. With its trend-setting measurement and communication technology in the fields of water quality, water quantity, meteorology, solar irradiation, data management and telemetry, the company contributes sustainably to protecting lives and the environment.

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