THERMOPILE SHADOWBAND RADIOMETER

MODEL TSR-1

BULLETIN TSR-1

Overview

The Model TSR-1 Thermopile Shadowband Radiometer is a scientific field instrument that simultaneously measures total, direct-normal, and diffuse irradiance across the entire solar spectrum from 300 nm to 2800 nm. The thermopile rotating shadowband instrument represents a major breakthrough in solar-radiation instrumentation, combining YES rotating shadowband radiometer technology with a true thermopile pyranometer to provide all components of solar irradiance with one instrument. With its advanced design, accuracy, high reliability, and automated remote operation, the TSR is the ideal solution for applications such as solar resource assessment.

The TSR is based on the field-proven YES multifilter rotating shadowband (MFR) technology, which was initially developed by scientists at the US Department of Energy's Pacific Northwest Laboratory for renewable energy research, and licensed to YES, Inc. Scientists and engineers at YES have made significant advances in the instrument technology to produce rugged and highly accurate instruments for atmospheric radiation measurements. These systems have been operating many years in the USDA's UVB monitoring network http://uvb.nrel.colostate.edu.

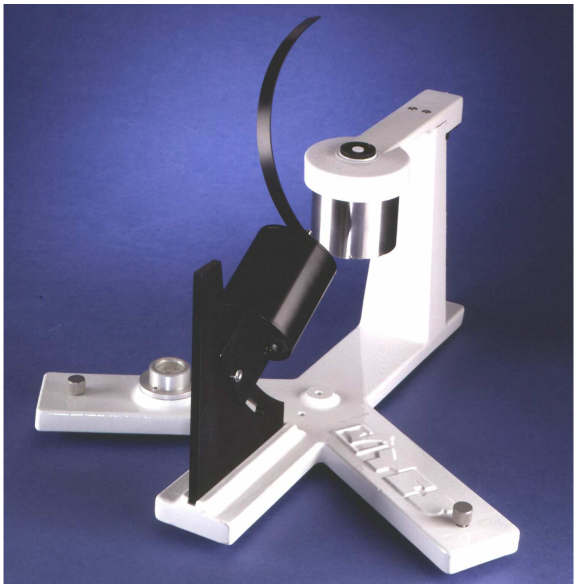
Features

The TSR offers the following key features:

- Thermopile pyranometer detector
- Angle-corrected direct-normal data
- Thermally stabilized detector
- Smart rotating shadowband
- Multichannel data acquisition and control (DAC) system for PV/thermal monitoring

Thermopile Detector Measures Entire Solar Spectrum

The TSR's thermopile detector is sensitive to solar radiation across the full spectral range of the sun, from 300 to 2800 nm, while silicon photodiode-based detectors are sensitive from only 400 nm to 1100 nm. This means that a thermopile's sensitivity captures a range about four times wider than a silicon detector, and therefore provides a much more accurate measurement of available solar resources.



Model TSR-1 Radiometer

Because the solar spectrum varies greatly throughout the day, so-called spectral "correction algorithms" cannot accurately compensate for the quite limited spectral range of a photodiode.

In addition to the thermopile's broadband response, another advantage of the design is that using a single detector to measure all three solar radiation components eliminates calibration errors introduced into the measurement by the use of multiple instruments, which require separate calibrations and have higher operating costs.

Measured Cosine Response Provides Angle-Corrected Data

An ideal Lambertian surface has a perfect cosine response: the light received is directly proportional to the cosine of the angle of incidence. Because no surface has a perfect Lambertian response, the angular error of the surface must be measured and then corrected in order to achieve 1% measurement accuracy. Each TSR is individually characterized in an optical facility to measure its angular (cosine) response. The data processing software then applies these cosine coefficients to the collected raw data to angle correct the direct-normal irradiance (DNI), to compensate for unique imperfections in the detector. A generic angular correction would provide inaccurate DNI results.

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Thermal Stabilization Circuitry Ensures Temperature Independence

All detectors experience shifts in sensitivity with changes in ambient temperature. To eliminate temperature dependence, the TSR uses a heater and precision thermal control circuit to maintain the thermopile detector at a stable constant temperature, which is slightly above the maximum anticipated ambient air temperature. The heater also helps to dry any dew and precipitation from the radiometer and keep water vapor out of the radiometer head, which helps maintain calibration stability. A humidity indicator on the side of the radiometer lets you know at a glance if the O-ring seals have been compromised.

Smart Shadowband Tracks Sun

When you install the TSR, you align and level the instrument and then initialize the system based on your site location. The system uses GMT time, site location parameters, and a precision solar ephemeris calculation to ensure the shadowband is aligned when making its shaded measurement. This provides the diffuse-horizontal irradiance. To compensate for the excess sky blocked during this shaded measurement, the system actually makes three shaded measurements when blocking the sun: one completely blocking the diffuser and then two to either side of the diffuser. The algorithms used by the TSR to perform a predictive, calculated block of the sun result in data that are significantly more accurate than data from systems that simply sweep the band and estimate the location of the sun. Such estimating (non-predictive block) rotating-shadowband sweep approaches are prone to measurement error due to the high variability in the diffuse component under partly cloudy conditions.

The *smart* rotating shadowband of the TSR system enables you to measure all three solar irradiance components with one instrument. Without the TSR, you need a normal incidence pyrheliometer (NIP) mounted on a 2-D altitude/azimuth sun tracker and two ventilated thermopile pyranometers mounted on the sun tracker with a shading disk. The NIP provides the direct-normal irradiance while the shaded pyranometer provides the diffuse irradiance; the other pyranometer provides the total irradiance. In contrast, a TSR contains just one moving part, the shadowband, and a single detector to maintain and calibrate, thus achieving the accuracy of the NIP/pyranometer/tracker configuration at a fraction of the cost. While sweeping-band systems employing photodiode detectors provide the advantages of a single detector approach, they lack the broadband performance and accuracy of the TSR.

Multichannel Data Acquisition and Control (DAC) System

In addition to controlling the shadowband, the embedded automatic control and data acquisition system can monitor up to 30 other analog signals for inputs such as PV or thermocouples, and/or a Model PTU-2000 pressure, temperature, and relative humidity met sensor. Up to six tower mounted anemometers can be configured at sites where wind resource assessment is desired.

The automated control system also enables remote operation via standard RS-232 serial data communications at unattended sites. It can be run from AC line with standby battery power, or via PV.

Specifications

ISO Classification	First Class, WRR traceable
Spectral Response	300 nm to 2800 nm MFR-7 includes thermopile channel and six additional channels: 415, 500, 615, 673, 870, and 940, each 10 nm FWHM for optical depth, column aerosol, and water vapor
Cosine Response	Better than 1% over 0-80° zenith angle for angle corrected DNI data; better than 5% for raw data
Response Time	< 1 second
Effective Field of View	5 degrees
Sensitivity Range	0-1500 W/m^2
Operating Range	-50°C to +50°C (+80°C storage)
Power Requirement	110/250 Vac, 50/60 Hz 50 Watts (max) or 12 Vdc 1A(typ),3A(max)
Sampling Rate	Up to 4 samples/minute
Communication	RS-232 port; 802.3 Ethernet option, GSM cell modem option, or user-supplied telco modem
System Memory	1 week standard, up to 6 months with memory expansion option

For more information

The TSR is based on the YES rotating shadowband radiometer technology. For more detail on the principle of operation of YES rotating shadowband instrumentation, refer to bulletin MFR-7.

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