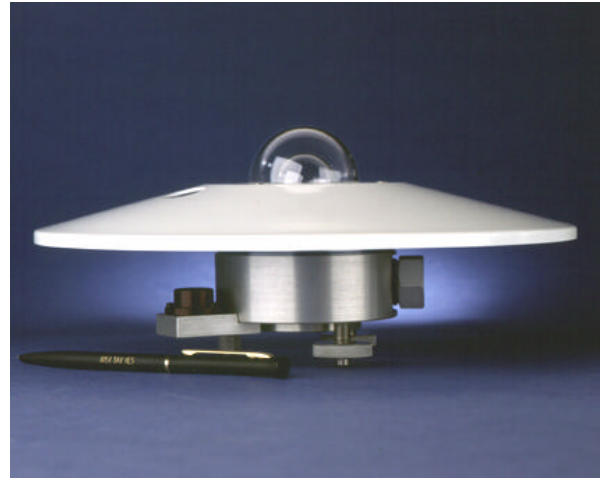


TOTAL SOLAR PYRANOMETER MODEL TSP-400

BULLETIN TSP-400



Model TSP-400 Total Solar Pyranometer

The output voltage of a single thermocouple used in a conventional pyranometer is approximately $22 \mu\text{V}/^\circ\text{C}$, so many junctions connected in series are required to produce a usable output voltage. The Seebeck coefficient of a bismuth telluride thermocouple is an order of magnitude greater than that of the conventional thermocouple; the TSP-400 typically produces $\approx 40 \text{ mVdc}$ for a solar irradiance of $1250 \text{ W}/\text{m}^2$ (max. 60 mVdc FS).

Applications

The TSP-400 is sensitive to radiation with wavelengths between 0.3 and $3 \mu\text{m}$, making it an ideal instrument for the measurement of incident solar radiation. Typical instrument applications include:

- Meteorological and climatological measurements
- Global warming and surface albedo studies
- Evaluation of solar energy systems
- Control of HVAC systems
- Remote-sensing ground truth experiments

Calibration Methodology

We calibrate each TSP-400 using the method recommended by the World Meteorological Organization. This method involves running co-located with a reference pyranometer on an outdoor test stand and then comparing the results.

$$p = \frac{\rho RT}{M}$$

$$S(\lambda) = S_0(\lambda) e^{-\tau \cdot \delta(\lambda)}$$

General Description

The Model TSP-400 Total Solar Pyranometer is a precision meteorological instrument that measures global (direct and diffuse) total solar radiation. It is ruggedly designed for long-term field use and available in either non-ventilated or ventilated configurations (Model TSP-400V). When properly characterized the Model TSP-400V meets or exceeds the World Meteorological Organization's requirements for *high quality* pyranometers (formerly called a *secondary standard*).

The TSP-400's innovative design preserves the basic principle of total solar radiation measurement, that is, relating the incident irradiance to the temperature difference between a radiation receiver and a shielded thermal reference. However, the TSP-400 uses a rugged metal solar radiation-receiving surface, thermally bonded to a modern bismuth telluride thermopile, to make the temperature measurement. The special design of the radiation-receiving surface results in an instrument with these features:

- Medium level, low-impedance ($<300\Omega$) output signal
- Superior linearity and long-term calibration stability
- Excellent cosine response completely free from axial asymmetry errors
- Freedom from the effects of changes in ambient temperature (no thermal correction is required by the user as with some older pyranometers)

The radiation receiving surface is protected by two domes, which block long-wave radiation and prevent conductive cooling of the radiation sensing element. The double-domed configuration also keeps the instrument weather-tight.

Instrument Development

The TSP-400 represents a major advancement in the field of total solar radiation measurement. Historically, total solar pyranometers have relied on thermopiles (bundles of copper-constantan thermocouples) to measure the temperature difference between a radiation-receiving surface and a shielded thermal mass.

$B(T) = 67^4$

$e_x(U) = \frac{r}{0.62197 + r}$

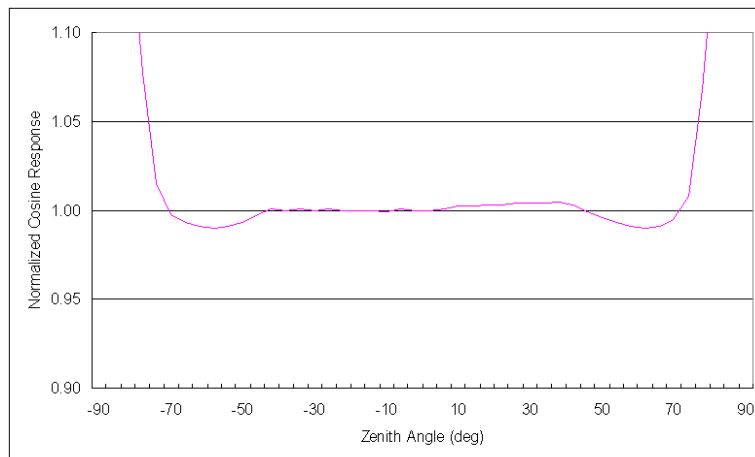
$\frac{dM}{dt} = \frac{M^2 \tan \phi}{a} + \frac{2\Omega v \sin \phi}{a} - \frac{1}{a} \frac{\partial p}{\partial \lambda} + \frac{2\Omega v \sin \phi}{a} - 2\Omega v \sin \phi + F_x$

Our reference pyranometer is traceable to an absolute cavity radiometer, which in turn is referenced to the WRR (World Radiometric Reference). The calibration method is conducted in accordance with ASTM Designation E 824-81, *Standard Method for Transfer of Calibration From Reference to Field Pyranometers*. This method is similar to the one described in ISO 9847, *Solar Energy — Calibration of field pyranometers by comparison to a reference pyranometer*, if you are more familiar with ISO procedures.

Calibration to "High Quality/Secondary Standard" is optionally available. Although not all High Quality characteristics are characterized for individual units, extensive testing has been conducted to characterize its cosine response, spectral response, and time response to prove that these parameters are uniform from unit-to-unit. Each system includes a calibration certificate, manual, and cables.

Mechanical Configuration

The TSP-400 is packaged in a rugged anodized aluminum enclosure with a outer powder-coated aluminum radiation shield. This radiation shield minimizes ground return and helps to isolate the instrument from solar warming. Its baked-on finish has shown to give superior performance in outdoor environments. Internal components are O-ring sealed. A bubble level is provided and a visible humidity indicator is backed up with a separate internal desiccant pack. Stainless steel leveling screws and two hold-down screw holes are provided on a 2.75 inch (6.985 cm) diameter



TSP-400 Cosine Response

bolt circle. Each TSP-400 package includes a calibration certificate and 3 meter cable.

Specifications

| | |
|-------------------------|---|
| Spectral Response: | 0.3 to 3 μm |
| Resolution: | 1 W/m^2 |
| Sensitivity: | Approx. $48\mu\text{V}/(\text{W}/\text{m}^2)$, output impedance $<200\ \Omega$, $\approx 40\ \text{mVdc}$ nominal (60 mVdc max FS) |
| Cosine Response: | Better than $\pm 1\%$ for a $\pm 75^\circ$ SZA; better than $\pm 2\%$ for a $\pm 85^\circ$ SZA |
| Temperature Dependence: | $< 1\%$ of F.S. over $\pm 50^\circ\text{C}$ ambient temperature range |
| Response Time: | $\approx 12\ \text{sec}$ (1/e response to a step change in incident irradiance) |
| Linearity: | 0.5% (0-1400 W/m^2) |
| Axial Asymmetry: | $< 0.1\%$ |
| Weight: | 3.2 kg (7 lb.) |

Cosine Response

Much of the TSP-400 design effort focused on producing an instrument with a superior cosine response, achieved by special attention to the radiation-receiving surface. A typical normalized TSP-400 cosine response is shown; the horizontal line at 1.00 would indicate a "perfect" response.



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