Calibration Report: Pyranometer CM22-040100

World Meteorological Organization number 39039
(For the Baseline Radiation Network)

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Calibration date: 2024-03-20.
Next calibration: 2026-03-20.
Reference standard: AHF-31041

The method here is described in "ISO 9846 Solar energy – Calibration of a pyranometer using a pyrheliometer, First edition 1993-12-01". The shade and unshade intervals have been extended to get several measurements on each cycle.

The calibration coefficients and their associated uncertainties (U95%) have been determined for a pyranometer. The pyranometer was mounted with the connector at an azimuth of approximately 195º with respect to the tracker, sun direction being azimuth = 0.0º. Data were collected during March of 2023, details are below. Only data between solar zenith angles of 40º and 50º were used. The calibration is traceable Through the Golden Colorado National Renewable Energy Laboratory's (NREL) September 2022 National Pyrheliometer Comparison (NPC) to the World Radiation Reference Maintained at the Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center. The NREL cavity reference group attended the International Pyrheliometer Comparison held in Davos during September and October of 2021.

The sensitivity factors and their associated uncertainties (95%) are as follows:

Sensor	S (μV/(W/m^2)) ± U95%	Method
CM22-040100 WMO number 39039	9.174 ± 0.688%	relative to CM22-060145

Application $I = (\mu V\ output)/S \pm sqrt(2)*U95\%$

Where: I = the irradiance measured by the pyranometer
(μV output) = microvolt output of the pyranometer
S = calibration coefficient of the pyranometer
U95% = the 95 % confidence level

Some supporting information, supporting plots, a list of past calibration values, and a brief description of the calibration process are presented below

CALIBRATION LOCATION
NASA Langley Hampton VA.
Latitude = 37.1038 deg., Longitude = -76.3872 deg., Elevation = 6 meters.

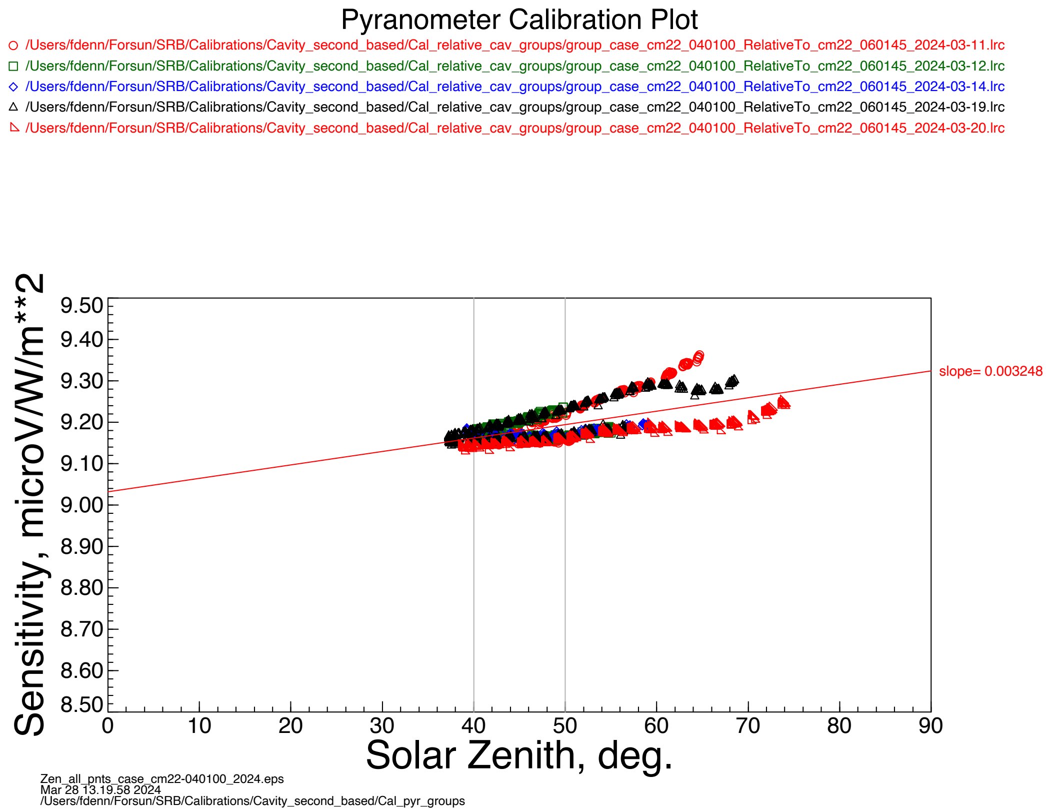
CALIBRATING PERSON(S)
Fred Denn, Bryan Fabbri

TRACEABILITY
The reference standard was Eppley Laboratories Inc., absolute cavity radiometer AHF31041, with its associated, Campbell 1000x based, data acquisition system. The cavity calibration is traceable first to the cavity working group at the National Renewable Energy Laboratory (NREL) in Golden Colorado, And through the NREL group to the World Radiation Reference (WRR), located at the Physikalisch-Meteorologisches Observatorium, in Davos Switzerland. The NREL working group attended the 2021 International Pyrheliometer Intercomparison (IPC). Cavity AHF31041 participated National Pyrheliometer Comparisons (NPC)s at NREL in September and October 2022 and 2023.

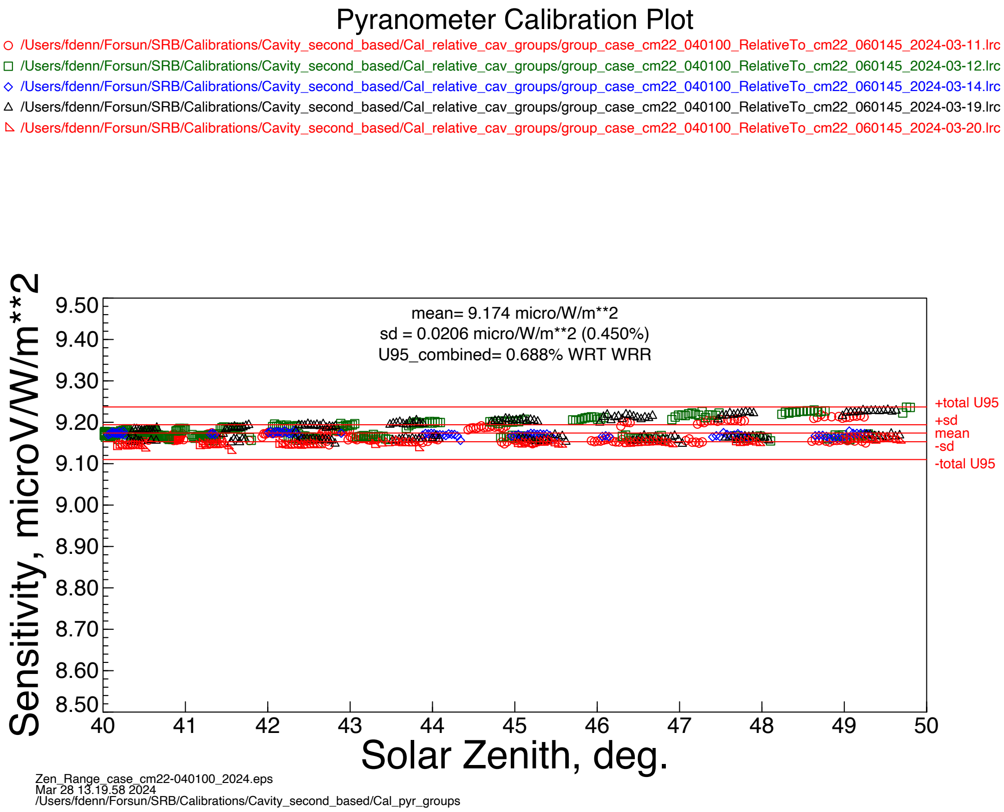
HARDWARE CONFIGURATION
The pyranometer was mounted on a Kipp Zonen sun tracker with the standard shading mechanism. The nut on the little bolt near the base of the tracker that holds the flat rod that holds the shading mechanism is removed. The flat bar is removed from the bolt and the shading ball mechanism is allowed to descend until it rests on the arm assembly to place the pyranometers in the unshaded (global) position. The flat bar is placed on the bolt to place the pyranometers in the shaded configuration. Pyranometers are placed in the global position for approximately five minutes, and it the shaded position for about five minutes.

DATA DAYS
Data were collected on the days listed below. Test pyrheliometer data are calibrated against cavity pyrheliometer data taken each second during runs of approximately twenty minutes generally starting on the hour and half hour.

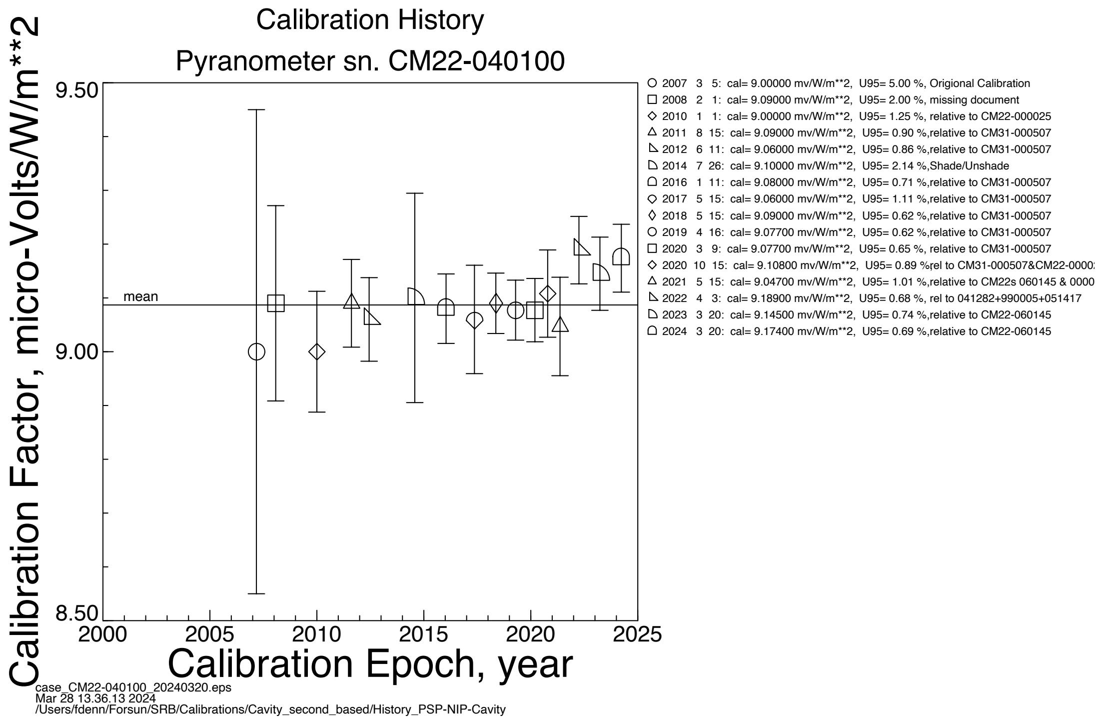
Date	hour range, UCT
2024-03-11	15.0 – 21.0
2024-03-12	14.5 – 19.5
2024-03-14	14.0 – 17.2
2024-03-19	14.0 – 21.5
2024-03-20	12.5 – 16.5



Calibration coefficients for, all zenith angles, several days. This displays the solar zenith angle dependance of the calibration values.



Calibration coefficients for several days. Each symbol represents an individual calibration value. The mean of these values will be taken to be the final calibration value. The overall U95 uncertainty is also displayed here. Data is limited to solar zenith angles 40º through 50º.



Calibration history for pyranometer CM22-040100. The solid horizontal line represents the mean value. The symbols and their error bars represent the mean and U95 of each calibration event. The column on the right presents numerical values for each calibration event and a brief description of the calibration method used.

CALIBRATION HISTORIES

Pyranometer: Kipp and Zonen CM22-040100

Date	S ($\mu V/W/m^2$)	U95 (%)	calibration type
2023-03-20	9.145	0.688	relative to CM22-060145
2022-04-03	9.189	0.683	rel to 041282+990005+051417
2021-05-17	9.047	1.01	relative to CM22s 060145 & 000025
2020-10-15	9.108	0.89	relative to CM31-000507
2020-03-09	9.077	0.65	relative to CM31-000507
2019-04-16	9.077	0.62	relative to CM31-000507
2018-05-15	9.09	0.62	relative to CM31-000507
2017-05-02	9.06	1.11	relative to CM31-000507
2016-01-11	9.08	0.71	relative to CM31-000507
2014-07-02	9.10	2.14 (%)	shade/unshade
2012-06-01	9.06	0.86 (%)	relative to CM31-000507
2011-08-02	9.09	1.316	Forgan's alternate
2010-01-01	9.00	1.316	Forgan's alternate
2008-02-02	9.09	1.316	Forgan's alternate
2007-03-05	9.00	5.00	manufacturers original

Photo of pyranometer CM22-040100 mounted on a fixed stand Note the position. North is to the right. This pyranometer has been calibrated and used in the same position. Although it is hard to see here there is a small hole in the sensor just inside the domes radially in form the mounting screw near the level. We have not seen a similar hole on any other pyranometers.

A Very Brief Description of the Calibration Process.

1) Pyranometers are mounted horizontally on an operating sun tracker.
2) Deploy the Cavity Radiometer, with the Campbell CR1000x data logger acquisition, collecting data each second. Postprocess the cavity data selecting stable data and passing 20 second interval data to the next step.
3) Modify the field radiometer program, so that a file of second data is produced in addition to the minute resolution data file.
4) Prepare the tracker hardware to operate in shade/unshade mode. Either in manual mode or with the automatic pneumatic cylinder.
5) Send the appropriate Campbell CRbasic to the cavities, preferably about 10 minutes before an hour or half hour. The system calibrates and runs continuously after that.
6) Collect pyranometer data in the unshaded configuration for about 5 minutes, and in the shaded configuration for about 5.0 minutes.
7) Continue this process while sky conditions permit, and cavity irradiance is greater than 700 Watts/meter**2. For pyranometers data between 40º and 50º solar zenith angle is sufficient.
8) Collect cavity and pyranometer data from the loggers to the data collection computer. Later transfer the collect data to the data processing computer.
9) Remove unstable (greater than 3 w/m**2 variation over 3 seconds) in the cavity data file. This is a post processing step.
10) Run a splitter program on the field radiometer file to generate a separate file for the shaded and unshaded periods for each instrument.
11) Run a plotting program on each data file so the data can be reviewed for: cloud events; bad shading; errors in the splitting routine; etc. Remove bad data records.
12) Run calibration programs to determine the calibration coefficient for each instrument.
13) Combine several days of calibration data to get a final calibration coefficient.
14) Produce a calibration document, such as this one, for each instrument. To be considered valid, a calibration must be documented and traceable to recognized standards, in this case the World Radiation Reference (WRR) in Davos Switzerland.