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PRECISION INFRARED RADIOMETER, MODEL PIR
Instruction Sheet

Introduction

The measuring of Atmospheric Radiation is generally divided in to two distinct spectral regions: the solar (shortwave) region and the terrestrial (longwave) region.

Solar radiation is a term used to describe visible and near-visible (ultraviolet and near-infrared) radiation emitted from the sun. The different regions are described by their wavelength range within the broad band range of 0.20 to 4.0 µm (microns). Terrestrial radiation is a term used to describe infrared radiation emitted from the atmosphere. The following is a list of the components of solar and terrestrial radiation and their approximate wavelength ranges:

Ultraviolet:	0.20 - 0.39 µm
Visible:	0.39 - 0.78 µm
Near-IR:	0.78 - 4.00 µm
Infrared:	4.00 - 100.00 µm

Approximately 99% of the solar radiation at the earth's surface is contained in the region from 0.3 to 3.0 µm while most of infrared radiation is contained in the region from 4.0 to 50 µm. Shortwave radiation is measured using pyranometers and pyrheliometers while longwave radiation is measured using a pyrgeometer.

Precision Infrared Radiometer

The PIR was a development of the Eppley Precision Spectral Pyranometer, Model PSP and continues to be the industry standard for precise measurement of incoming or outgoing longwave radiation. The PIR comprises the same wirewound thermopile detector and temperature compensation circuitry as found in the PSP. This thermopile detector is used to measure the "net radiation" of the PIR and a case thermistor (YSI 44031) is used to determine the outgoing radiation from the case. A dome thermistor is also included if one wishes to measure the dome temperature as compared to the case temperature to make any "corrections" to the final result.

Also included but being discontinued is circuitry for the "Simple Method" of operation. Years ago, when measuring thermistors was fairly difficult for routine users, some researchers opted to use the simple method to measure the solar radiation. A battery – thermistor – shunt resistor circuit was included and created a signal that would approximate the instrument's outgoing radiation and was measured in series with the thermopile's net signal. This method was not as precise but more convenient for many people as only one analog signal was measured and a single calibration constant applied. These batteries are no longer manufactured and there is no direct replacement.

To shield the thermopile from shortwave radiation, Eppley uses a silicon hemisphere with a vacuum deposited filter on the inside dome. The transmittance of this dome resembles that of silicon with a sharp lower cut-on between 3.5 and 4 microns. **Please do not remove the dome for any reason.**

Installation and Maintenance

The PIR should be free from obstructions (artificial and natural) above the plane of the sensing element. If this is not possible, the site selected should be as free as possible from shadows or artificial sources. An accessible flat roof usually provides a good location. In the case of downward looking PIRs (to measure outgoing radiation from the Earth), the field of view should also be as free as possible from obstructions.

If you are locating this instrument at a site where an Eppley SMT Automatic Tracker is present, you may wish to mount the PIR into the Eppley Shade Disk Kit, Model SDK. The SDK allows for the shading and ventilating of up to two instruments – usually one PIR for longwave measurements and one shade pyranometer such as the PSP or 8-48 for Diffuse Shortwave Measurements.

The PIR should be leveled using the three leveling screws and spirit level and then securely attached to whichever mounting stand is decided upon using the holes provided in the instruments baseplate (4.75" diameter bolt circle). By convention, the connector should face north in the Northern Hemisphere and South in the Southern Hemisphere to reduce solar load.

A Bendix/Amphenol 10 pin mating connector is supplied with the instrument Eppley recommends using weather proof cable (No 22 gauge, twisted shielded pair) such as Beldin 9540. For easy disassembly of the mating connector, unscrew the outer most section while it is connected to the PIR.

Pin designations are as follows:

Thermopile Output	A(-) & C(+)
Case Thermistor (YSI 44031)	D & E
Dome Thermistor (YSI 44031)	F & G
Case Ground	H
Not Used	J & K
Simple Method (obsolete)	A(-) & B(+)

Please refer to the Datalogger's Instructions or connecting the cable to the datalogger.

PIRs in continuous operation should be inspected regularly (daily if possible). At these inspections, the dome should be cleaned with a lint free soft cloth, being careful not to scratch the surface. The desiccator should be inspected and if the silica gel is pink or white in color, it should be replaced or rejuvenated by drying in an oven at about 135°C for a few hours.

Many researchers have had success in keeping the domes free from frost, snow, dew and moisture build-up by using the Eppley Ventilator, Model VEN or Shade Disk Kit, Model SDK to continuously blow air over both the instrument case and dome.

Operation

Simple Method (now obsolete). As the Radiation Compensation Circuit across pins B&C were included using the internal battery-thermistor-resistor circuit was designed to approximate the electrical output equivalent of the PIR's outgoing radiation, the simple method allowed one to simply measure the voltage across pins A&B and divide by the instrument sensitivity (Eq. 1).

$$R_{in} = V_{ab} / S \qquad \text{Eq. 1}$$

where R_{in} is the Incoming Radiation, V_{ab} is the Voltage and S is the Instrument's Sensitivity (approximately 4 $\mu V / Wm^{-2}$)

Precise Method (now required). The thermopile output voltage across pins A&C (V_{ac}) is divided by the sensitivity to determine the net radiation R_{net}. Note that R_{net} is typically negative as the PIR is emitting out into the atmosphere. The cases outgoing radiation R_{out} is calculated by multiplying the Stefan Boltzmann constant ($\sigma = 5.6704 \times 10^{-8}\ Wm^{-2}\ K^{-4}$) with the absolute Temperature of the case, T_c raised to the fourth power. The incoming radiation is then determined using Equation 2.

$$R_{in} = R_{net} + R_{out} = V_{ac} / S + \sigma T_c^4 \qquad \text{Eq. 2}$$

The case temperature, Tc, is determined by measuring the resistance across pins D&E and using the relationship:

$$T = 1 / \{C_1 + C_2 * Ln(R) + C_3 * (Ln(R))^3\}$$

where T is the absolute temperature, R is the measure resistance of the YSI thermistor in ohms, Ln indicates the natural logarithm and the values of the constants are:

$C_1 = 0.0010295$
$C_2 = 0.0002391$
$C_3 = 0.0000001568$

To obtain temperatures in °C, subtract 273.15 from the calculated temperature.

Example: Data taken from Eppley's Research Building on an April Day

Sensitivity:	S	4.18 µV / Wm^{-2} (from Certificate)
PIR Output:	V_{ab}	1,116 µV
Thermopile Output:	V_{ac}	-590 µV
Case Temperature:	T_c	12.79 kΩ = 292.13 K

(Eq.1) $1116 / 4.18 = 267.0\ Wm^{-2}$
(Eq. 2) $-590 / 4.18 + (5.6704x10^{-8})*(292.13)^4 = -141.1 + 413.0 = 271.9\ Wm^{-2}$

Many researchers have been concerned with the "dome heating effect". If the dome heats up more than the case, it may be radiating back onto the thermopile. Several formulas have been offered to account for the gradient but the most common was presented by Albrecht and Cox (*Journal of Applied Meteorology* Volume 16, February 1977). Expanding Eq. 2 above to read

$$R_{in} = V_{ac} / S + \sigma T_c^4 - k\sigma(T_d^4 - T_c^4) \qquad \text{Eq. 3}$$

where k is a constant and T_d is the dome temperature. Note that if $T_d = T_c$, this term is zero. Eppley calibrations do not determine the dome constant k but many researchers use 3.5 or 4.

Calibration

The fundamental calibration of IR detectors is based upon their exposure to an ideal blackbody radiator. At the Eppley Laboratory, the reference blackbody is a water-bath controlled, hemispherical, low temperature (0-50°C) source. The blackbody temperature is measured with an RTD temperature probe with traceability to the International Practical Temperature Scale (IPTS). Calibration results are derived from two distinct temperature settings and are supplemented by comparisons with witness standards. Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

An alternate method of calibration is to compare the PIR against a second, calibrated working standard PIR using a good source of steady longwave radiation (such as a cloudless night sky).

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