NREL Transforming ENERGY

Absolute Cavity Pyrgeometer (ACP)

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Overview

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-Description

-Why unique?

-Measurement Equation

-Outdoor measurement

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Purpose

-Measure atmospheric longwave irradiance.

-ABSOLUTE measurement traceable to International System of Units (SI).

-To date: Interim world reference traceable to blackbody (not sky/atmosphere), World Infrared Standard Group (WISG).

-InfraRed Integrating Sphere (IRIS) Developed by the World Radiation Center (PMOD) is traceable to blackbody irradiance.

-ACP is self calibrated radiometer using heat substitution like Absolute Cavity Radiometer (ACR) that is self calibrated radiometer using electrical substitution to measure solar irradiance.

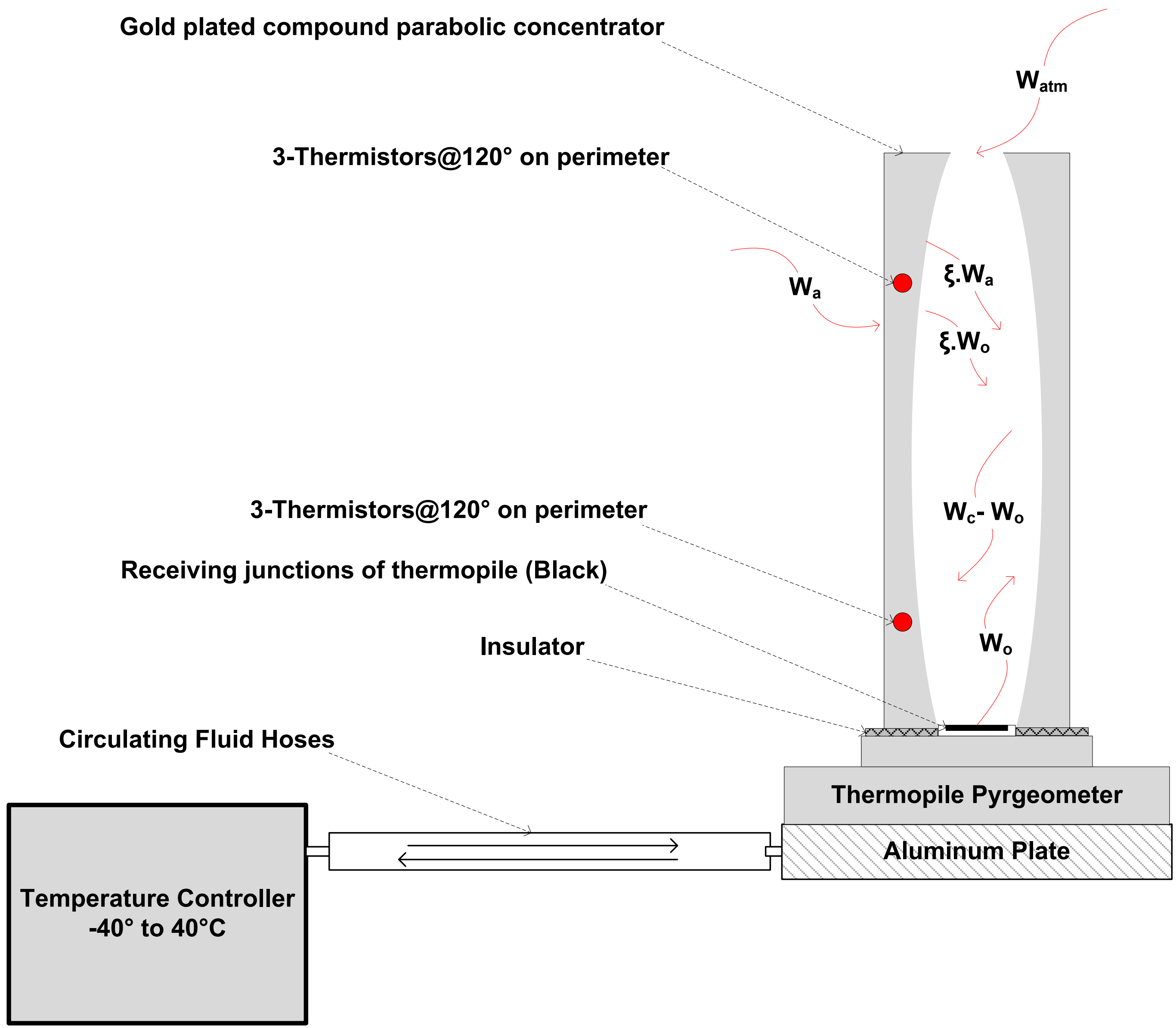
- ACP is a contribution to develop the world reference with traceability to SI, using the outdoor irradiance as the source, instead of blackbody.

Applications

ACP is traceable reference instrument to calibrate instruments used in the following applications:

1. Renewable-Energy: Thermal systems, window efficiency, resource assessment/maps, PV efficiency, solar and wind energy.
2. Atmospheric science: Cloud cover, meteorology, earth energy budget/profile, climate study.
3. Agriculture.
4. InfraRed thermometry.
5. Military.

Absolute Cavity Pyrgeometer, ACP



Updated Design of ACP with temperature controller and gold-plated cover to Protect Thermistors

Why Unique?

-Uses the outdoor irradiance as the reference source.

-Independent from the outdoor irradiance value and spectral distribution.

-Traceable to SI.

-All other systems are traceable to blackbody irradiance; indoor/outdoor spectral mismatch.

-Based on the simple pyrgeometer equation:

$$W_{net} = K_1 * V_{tp} = W_{in} - W_{out}$$

where, W_{net} = net irradiance, K_1 = reciprocal of the responsivity, V_{tp} = thermopile voltage, W_{in} = incoming irradiance, W_{out} = outgoing irradiance.

-The simple idea of the ACP is to cool the pyrgeometer receiving thermopile junctions' during calibration till V_{tp} = 0 microvolt; then:

$$W_{in} = W_{out}$$

Therefore; the measured atmospheric longwave irradiance = the outgoing irradiance which is traceable to the temperature scale ITS-90 with respect to SI units.

Measurement Equation

$$K_1 * V_{tp} = \boldsymbol{\tau} * W_{atm} + (1 + \boldsymbol{\varepsilon}) * W_c - (2 - \boldsymbol{\varepsilon}) * K_2 * W_r$$

- By cooling the ACP case temperature, and since W_{atm} is stable, then,

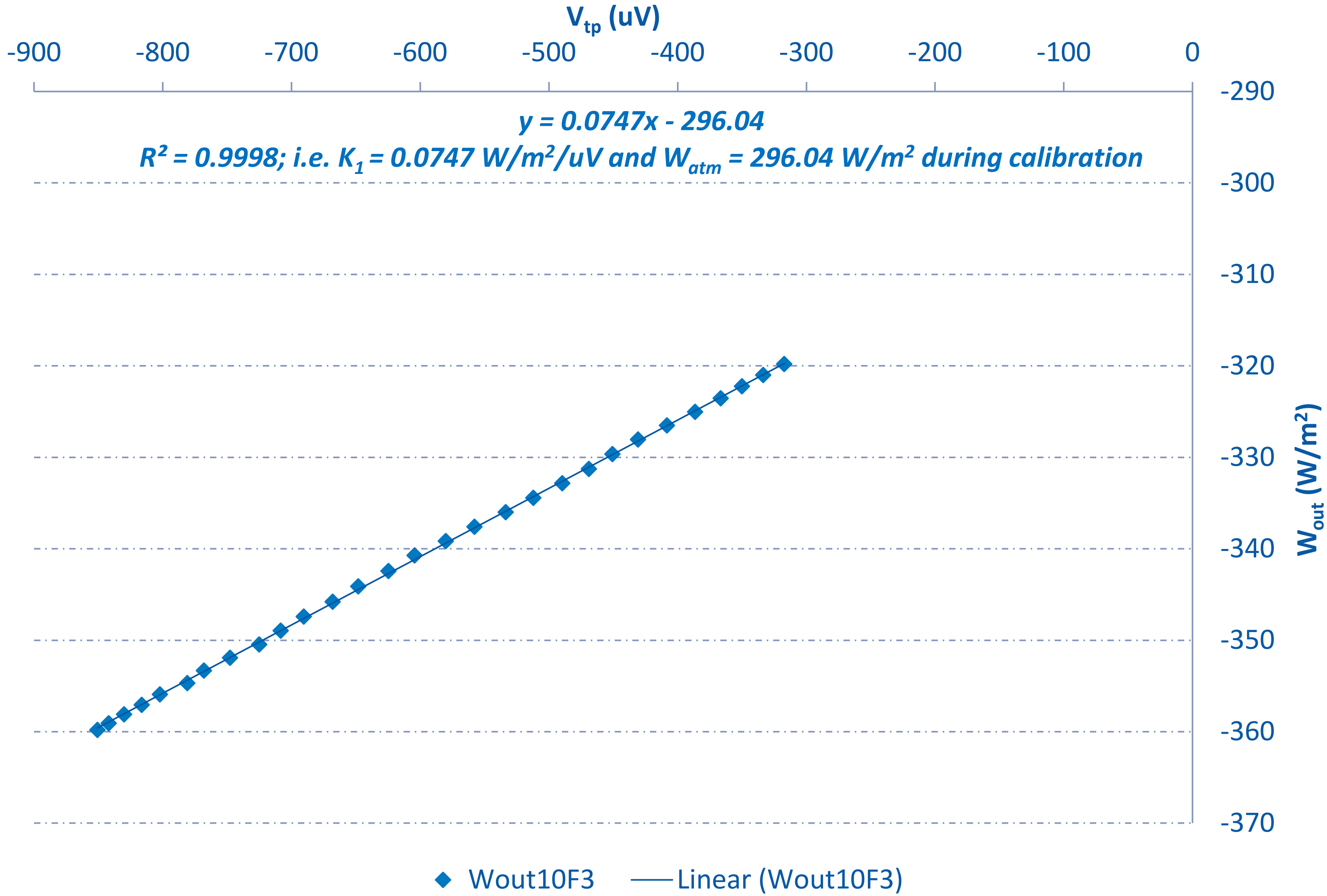
$$K_1 = \frac{(1 + \boldsymbol{\varepsilon}) * \Delta W_c - (2 - \boldsymbol{\varepsilon}) * K_2 * \Delta W_r}{\Delta V_{tp}}$$

- Then the atmospheric longwave irradiance is,

$$W_{atm} = \frac{K_1 * V_{tp} + (2 - \boldsymbol{\varepsilon}) * K_2 * W_r - (1 + \boldsymbol{\varepsilon}) * W_c}{\boldsymbol{\tau}}$$

τ = concentrator's throughput, ε = Gold emittance, $W_c = \sigma\, T_c^4$ where σ is Stefan Boltzmann constant = $5.6704*10^{-8}$ $W.m^{-2}.K^{-4}$, T_c = average temperature measured by 6 thermistors installed in the concentrator's wall in Kevin, K_2 = emittance of thermopile black surface = 1, $W_r = \sigma(T_{case}+K_4 V_{tp})^4$, T_{case} is the pyrgeometer's case temperature in Kelvin, K_4 is the thermopile efficiency factor = 0.0007044 K. uV^{-1}.

Variable W_{out} Irradiance vs Thermopile Output



ACP&IRIS Results during IPC-XIII

	Average Difference (W/m^2)	SD	Readings
ACP10F3-ACP57F3	-1.00	1.84	835
ACP10F3-ACP95F3	-0.14	1.10	538
ACP10F3-ACP96F3	-0.06	0.95	745
ACP10F3-IRIS2	1.56	1.39	835
ACP10F3-IRIS3	0.67	1.10	835
ACP10F3-IRIS4	0.71	1.38	835
ACP10F3-IRIS5	1.91	1.32	835
ACP(average) –IRIS(average)	1.61	1.26	835
ACP&IRIS(average) – WISG	3.33	1.61	835

Conclusion

-ACP is New, unique, and traceable to SI rather than a blackbody

-ACP contributes to establishing an Internationally recognized reference for measuring the atmospheric longwave irradiance

Reference: Reda, I., J. Zeng, J. Scheuch, L. Hanssen, B. Wilthan, D. Myers, and T. Stoffel (2012), *An absolute cavity pyrgeometer to measure the absolute outdoor longwave irradiance with traceability to International System of Units, SI*, J. Atmos. Sol. Terr. Phys., 77, 132– 143, doi:10.1016/j.jastp.2011.12.011.