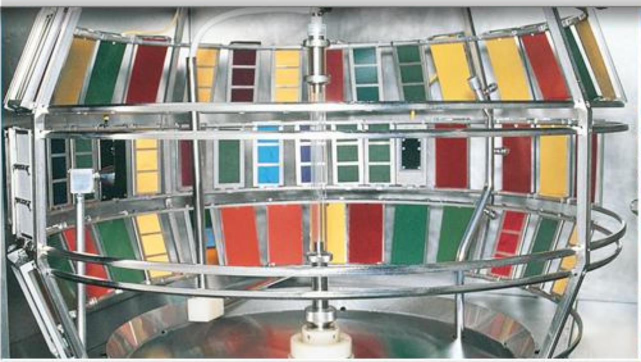
ATLAS
MATERIAL TESTING SOLUTIONS

AMETEK
MEASUREMENT & CALIBRATION TECHNOLOGIES

MATERIAL SCREENING | SERVICE LIFE SOLUTIONS | OUTDOOR WEATHERING TESTING



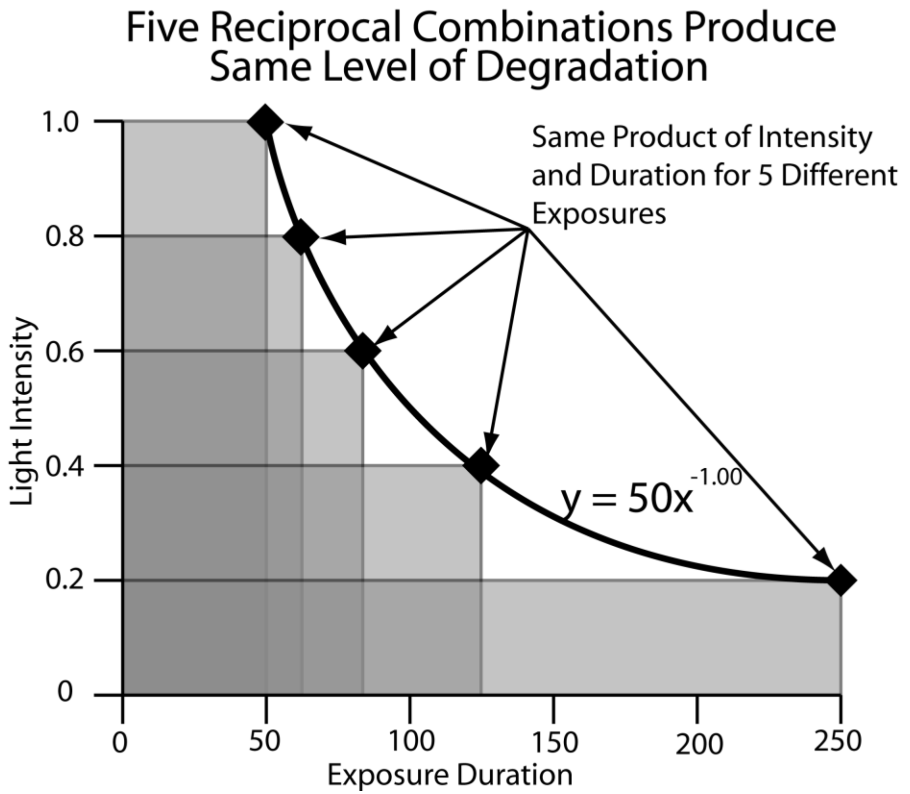
Ultra- Accelerated Weathering II: Considerations for Accelerated Data Based Weathering Service Life Predictions

Henry K. Hardcastle
Director R&D, IP Leader

2004 Sedona SLP Symposium

A New Approach to Characterizing Reciprocity, Hardcastle

(Presented at 3rd International Symposium on Service Life Prediction,
National Institute for Standards and Technology, February 1-6, 2004, Sedona, Arizona)



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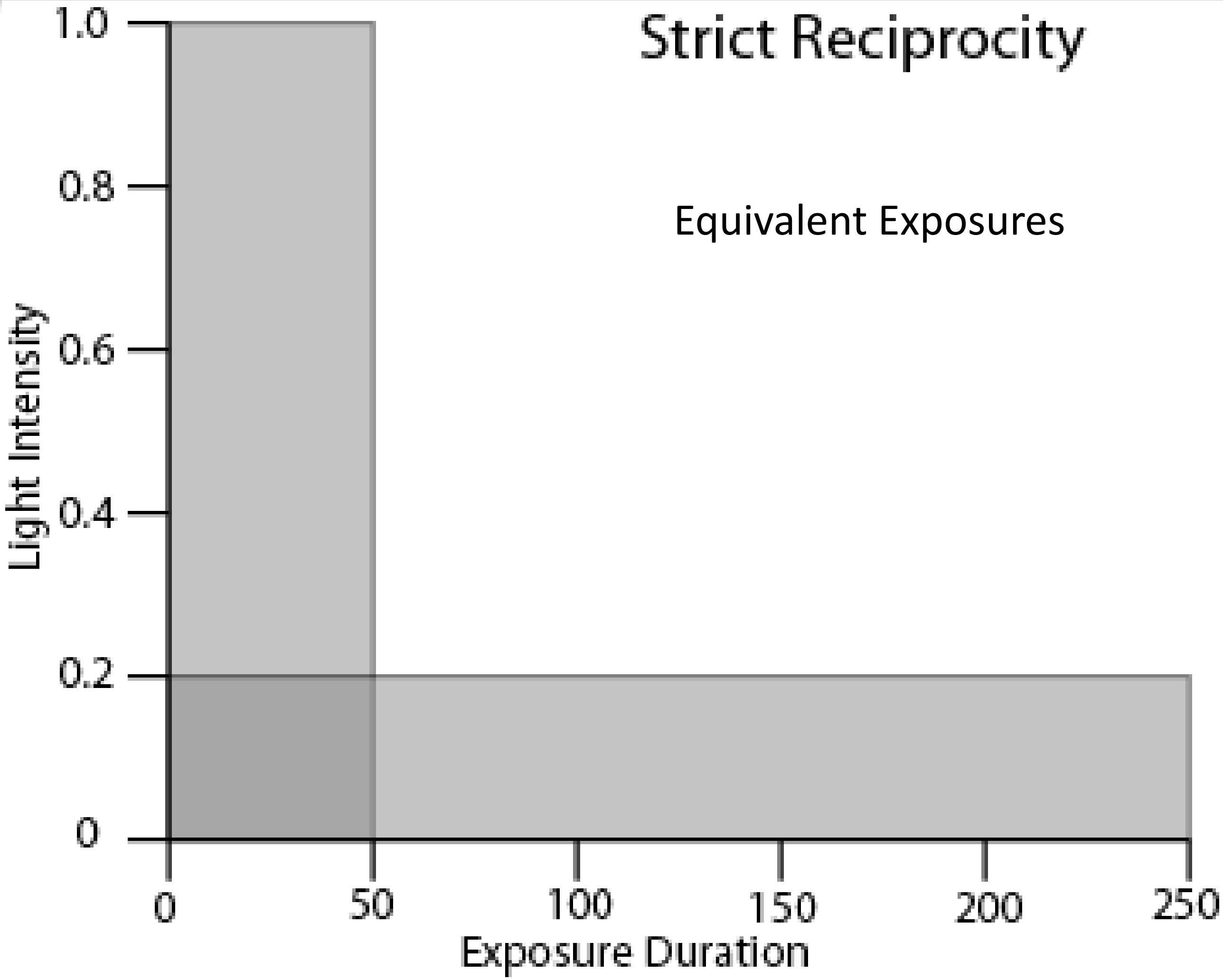
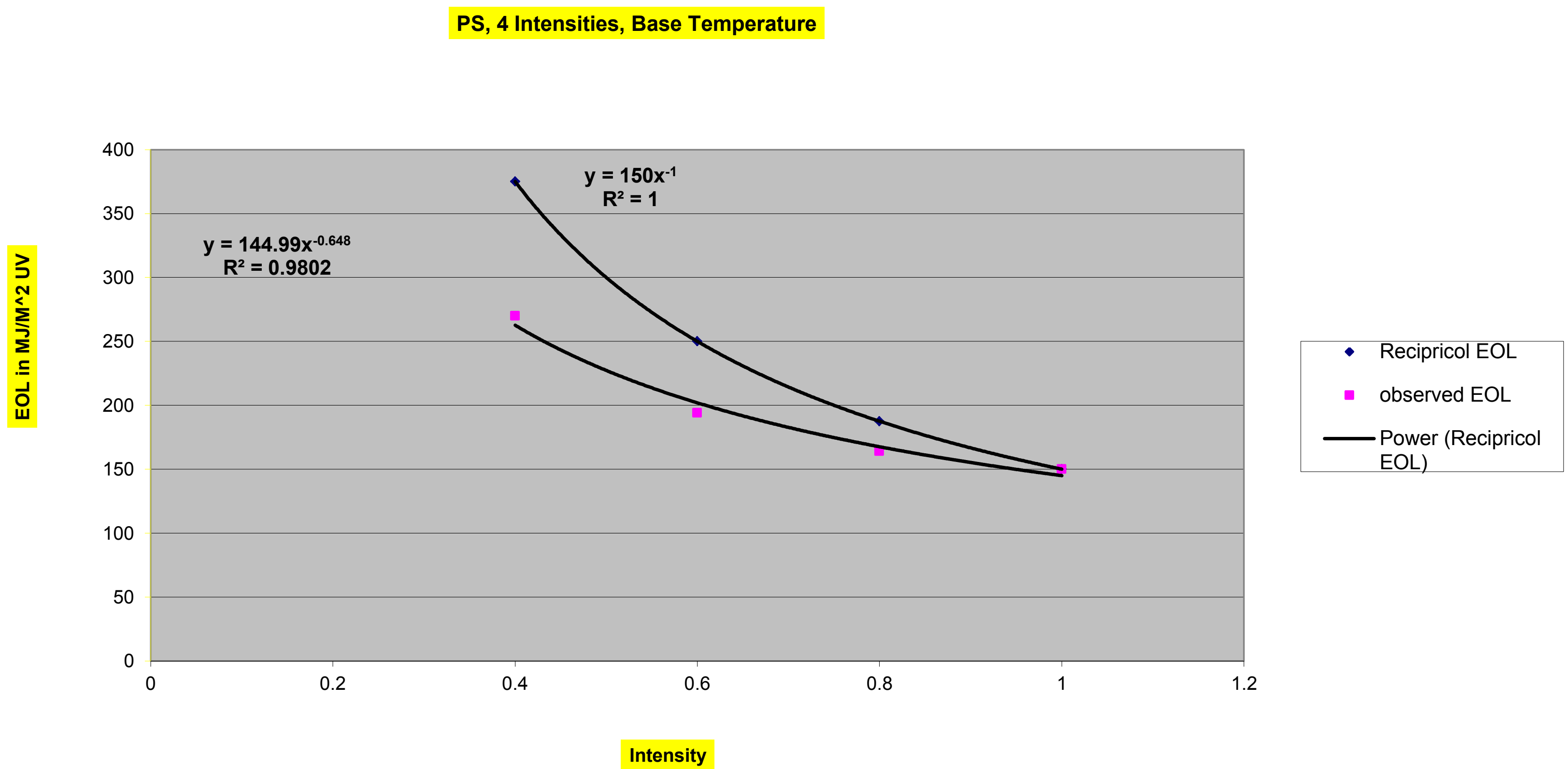


308 MJ/m^2 295-385nm

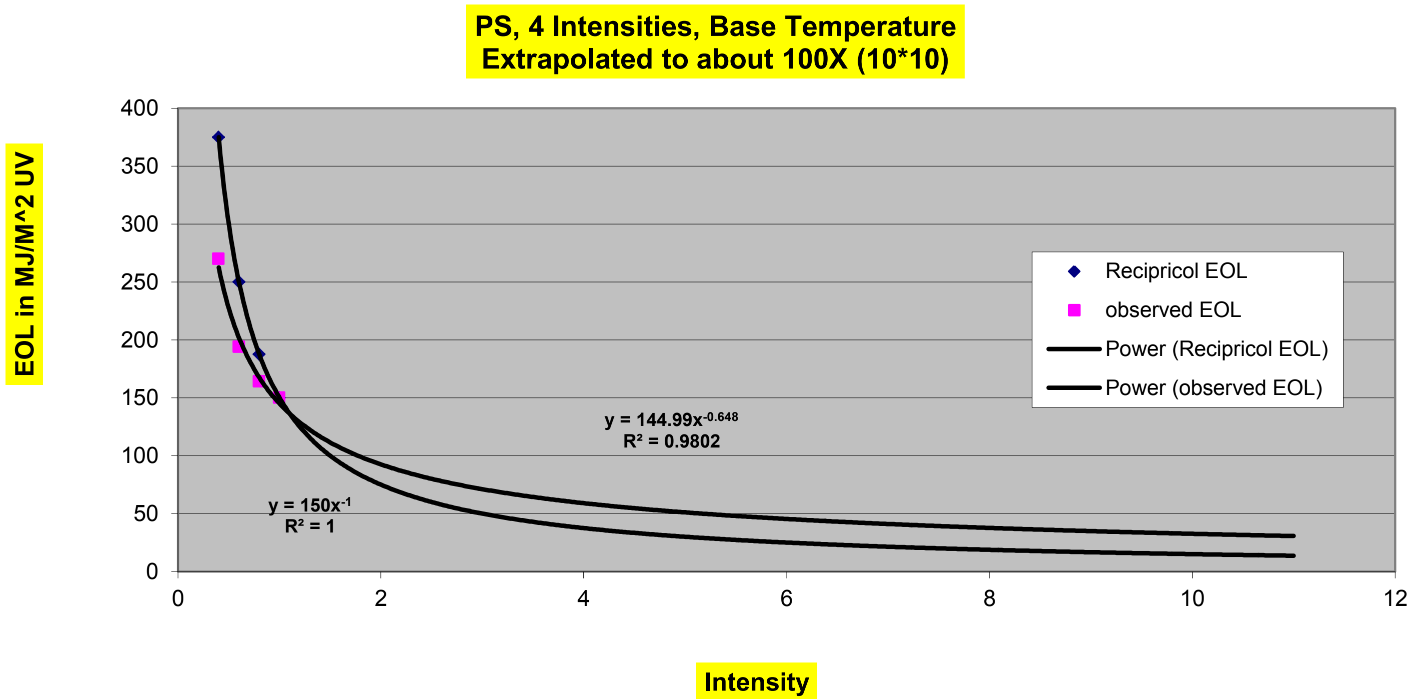
2004 Sedona SLP Symposium

- In That Paper We Described:
- Had to Invent the Apparatus to Test:



2004 Sedona SLP Symposium

- At that time NIST, Atlas and NREL were proposing very high UV irradiance exposures
- The last slide I showed a hypothesis to test: Had to develop more apparatus



EWS Gothenburg

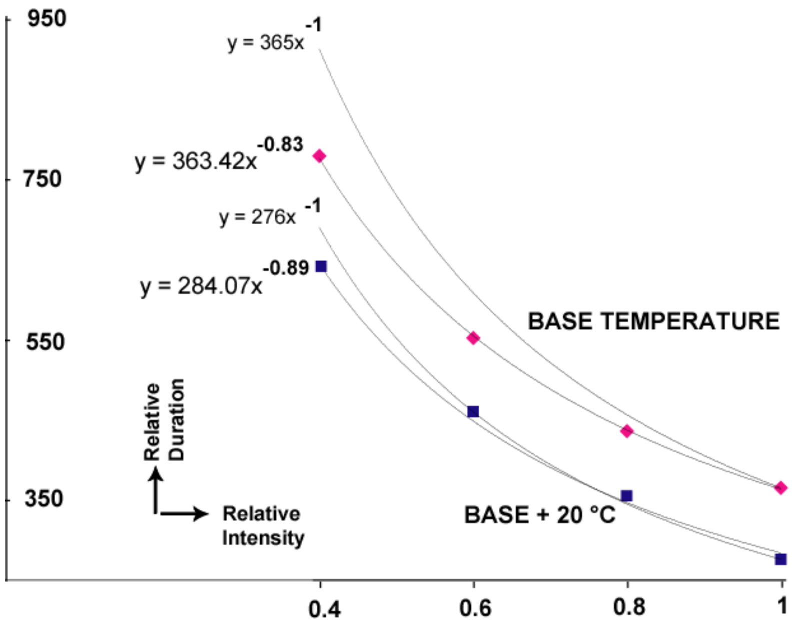
A Characterization of the Relationship Between Light Intensity and Degradation Rate for Weathering Durability, Hardcastle
(Presented at 2nd European Weathering Symposium EWS, Confederation of European Environmental Engineering Societies, June 16 and 17, 2005)

Predictive Model With 3 Intermittent Terms
Ln (Life Estimate in KJ/m^2 at 340nm) =
-4.655 + 3704(1/BPT °K) + 0.843 (UV in W/m^2 at 340nm) +0.002(RH%)

Time	Temperature	UV Light Intensity	Moisture	Contribution
6:00	21.574	0	98.1915	a
6:30	21.425	0	98.515	b
7:00	21.816	0	98.7785	c
7:30	22.135	0.00012	98.5315	d
8:00	22.528	0.001355	97.6765	e
8:30	23.026	0.003765	97.353	f
9:00	26.884	0.0229	94.377	g
9:30	28.903	0.028795	90.502	h
10:00	21.18	0.03157	87.3715	I
10:30	25.255	0.040735	85.947	j
11:00	25.5415	0.046265	83.278	k
11:30	31.692	0.051115	81.2	l
12:00	30.569	0.04712	78.535	m
12:30	33.651	0.05621	76.21	n

Total Degradation 06:00 to 12:30 =

Sum (a through n)



NIST SLP Symposium Key Largo

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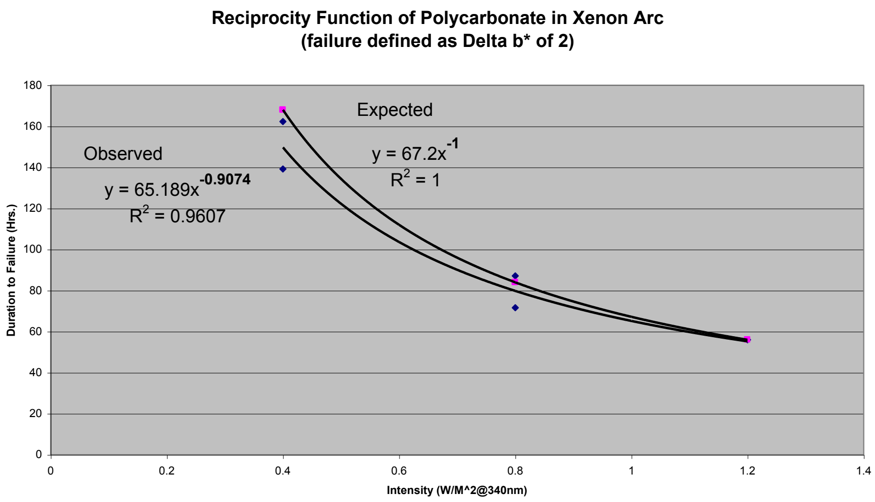
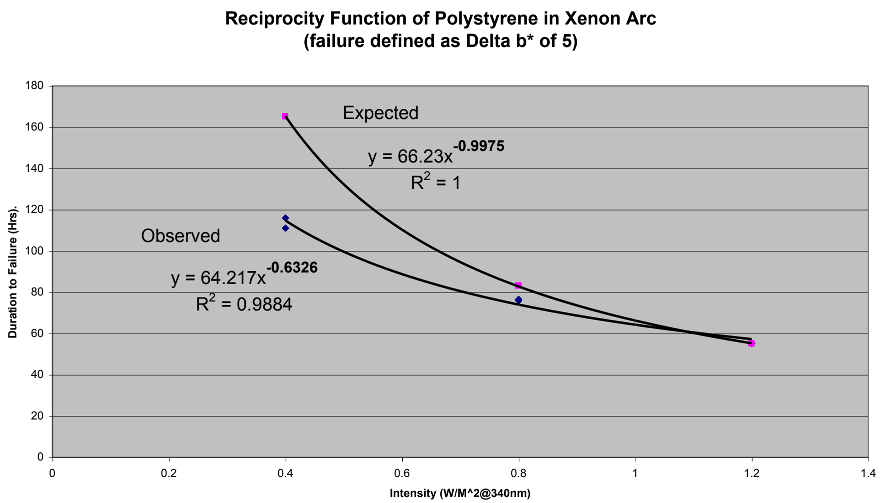
A New Approach to Characterizing Weathering Reciprocity in Xenon Arc Weathering Devices, Scott, Hardcastle

(Presented at The 4th International Symposium on Service Life Prediction, National Institute for Standards and Technology, December 3-8, 2006, Key Largo, FL)





ULTRA-ACCELERATED WEATHERING SYSTEM

- Background for UAWS
- UA Weathering Definition

Energy Balance: A Core Competency Of Our Technology

$$\alpha Q = 2h_{conv}\,[T_{samp}-T_{amb}] - \varepsilon\sigma[T^4{}_{sky} - T^4{}_{samp}] - \varepsilon\sigma[T^4{}_{back} - T^4{}_{samp}]$$

$$h_{cond} = k(\Delta T/\Delta x)$$

$$Q = 1000\ W/m^2(X)\ \text{vs.}\ Q = 201W/m^2(X)$$

Comparison of BPT Temperatures for Total Solar vs. UV Only Mirrors

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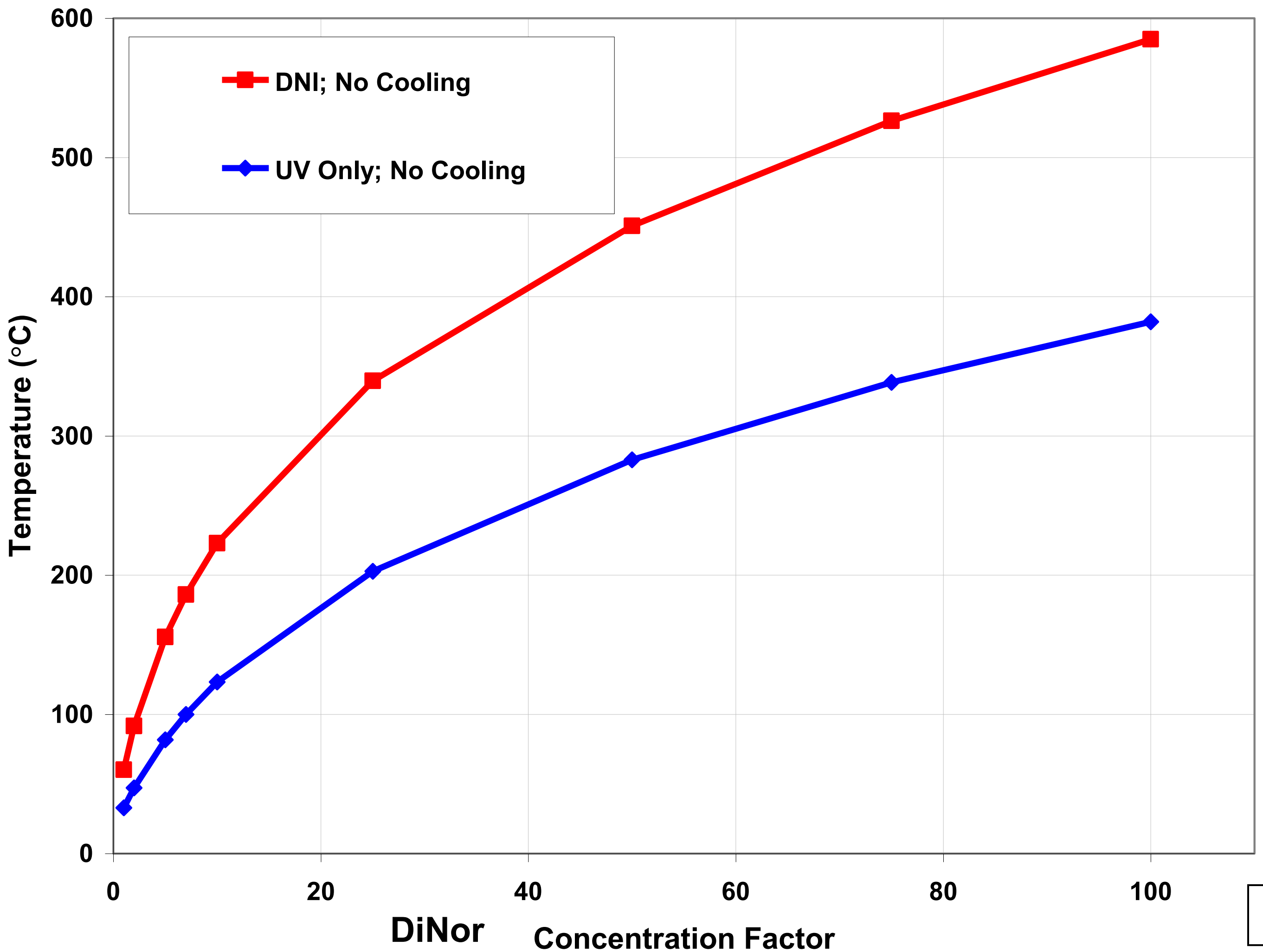

NREL/Jorgensen

Comparison of BPT Temperatures for Total Solar vs. UV Only Mirrors

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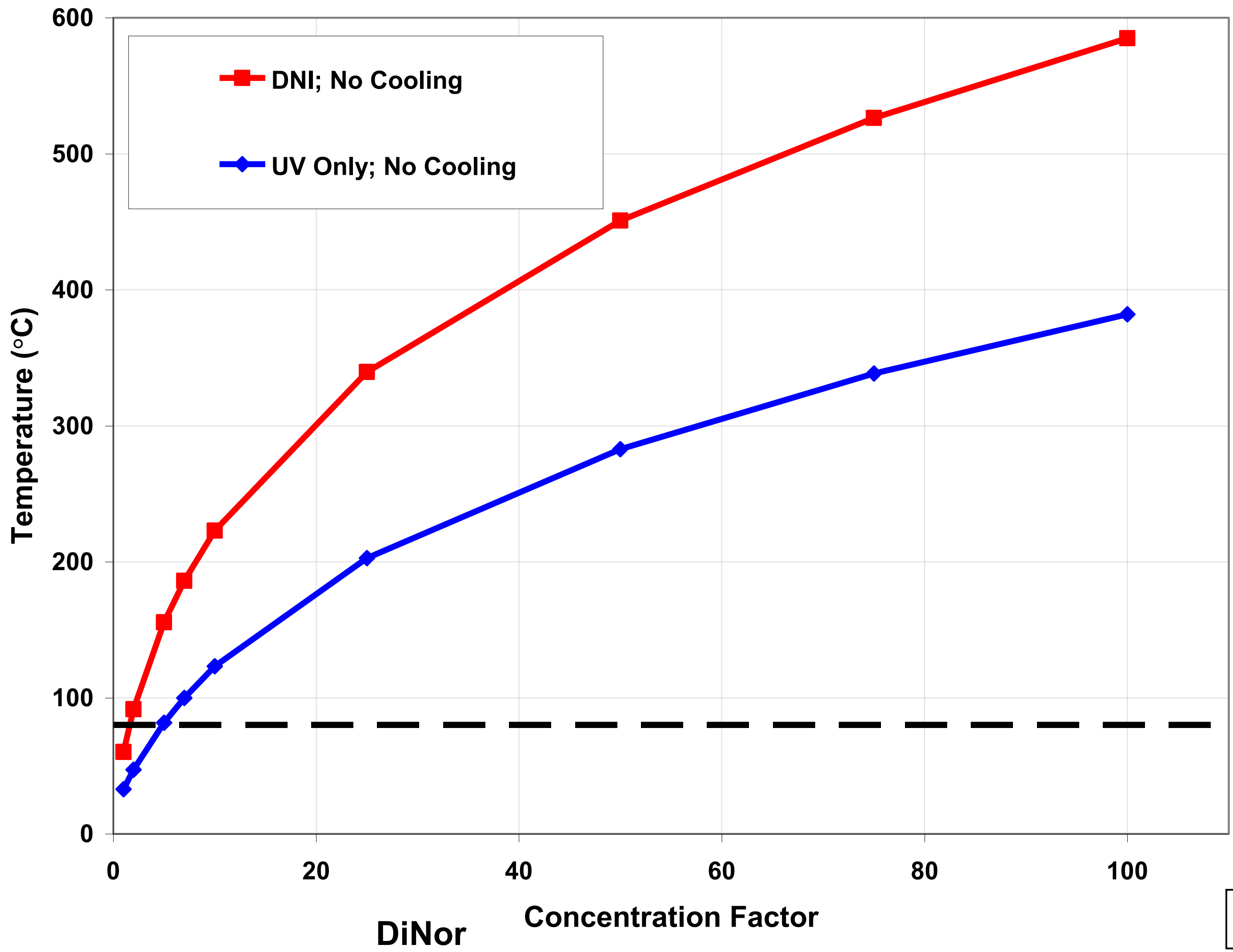

NREL/Jorgensen

Comparison of BPT Temperatures for Total Solar vs. UV Only Mirrors

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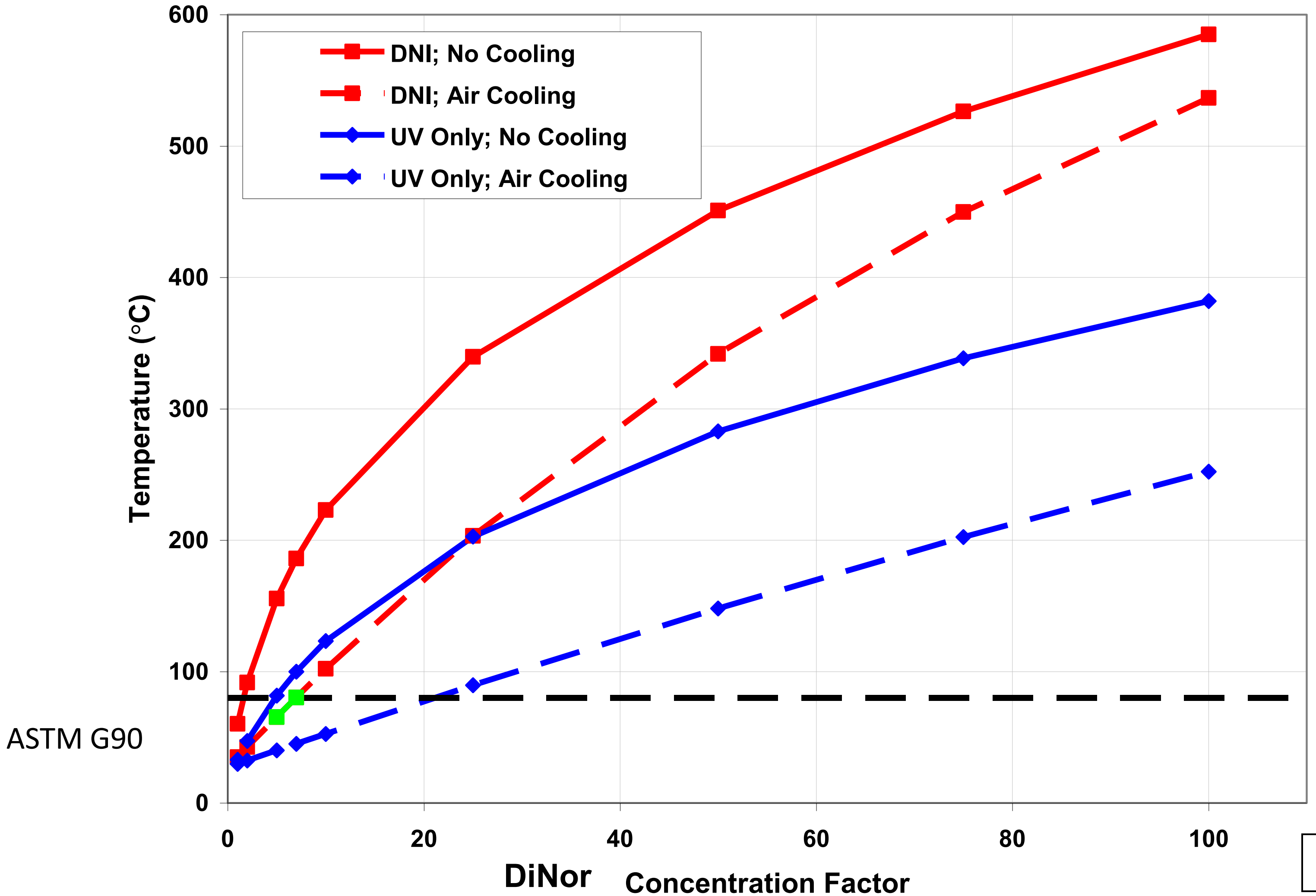
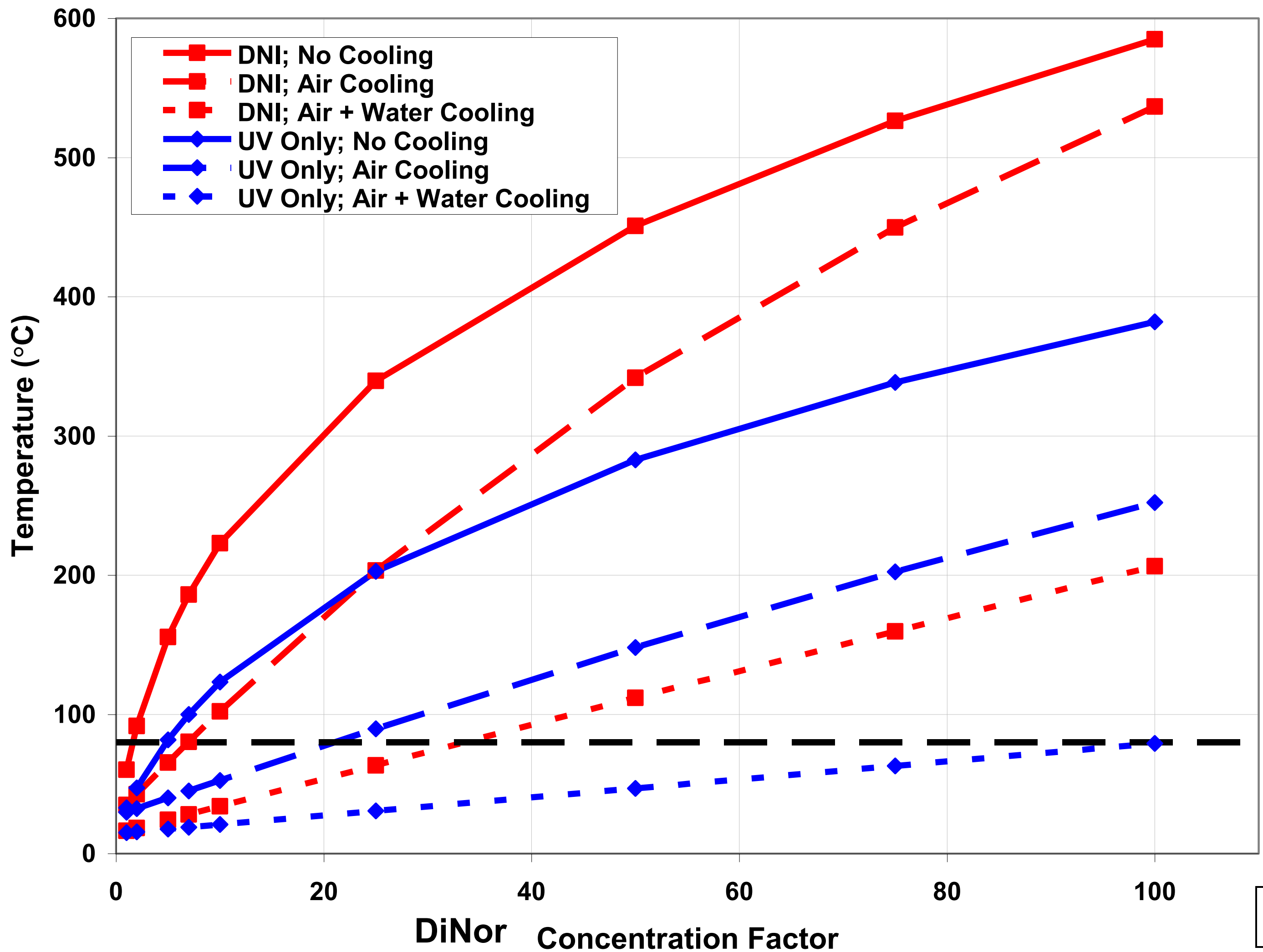


NREL/Jorgensen

Comparison of BPT Temperatures for Total Solar vs. UV Only Mirrors



NREL/Jorgensen

A New Class of Weathering Methodology

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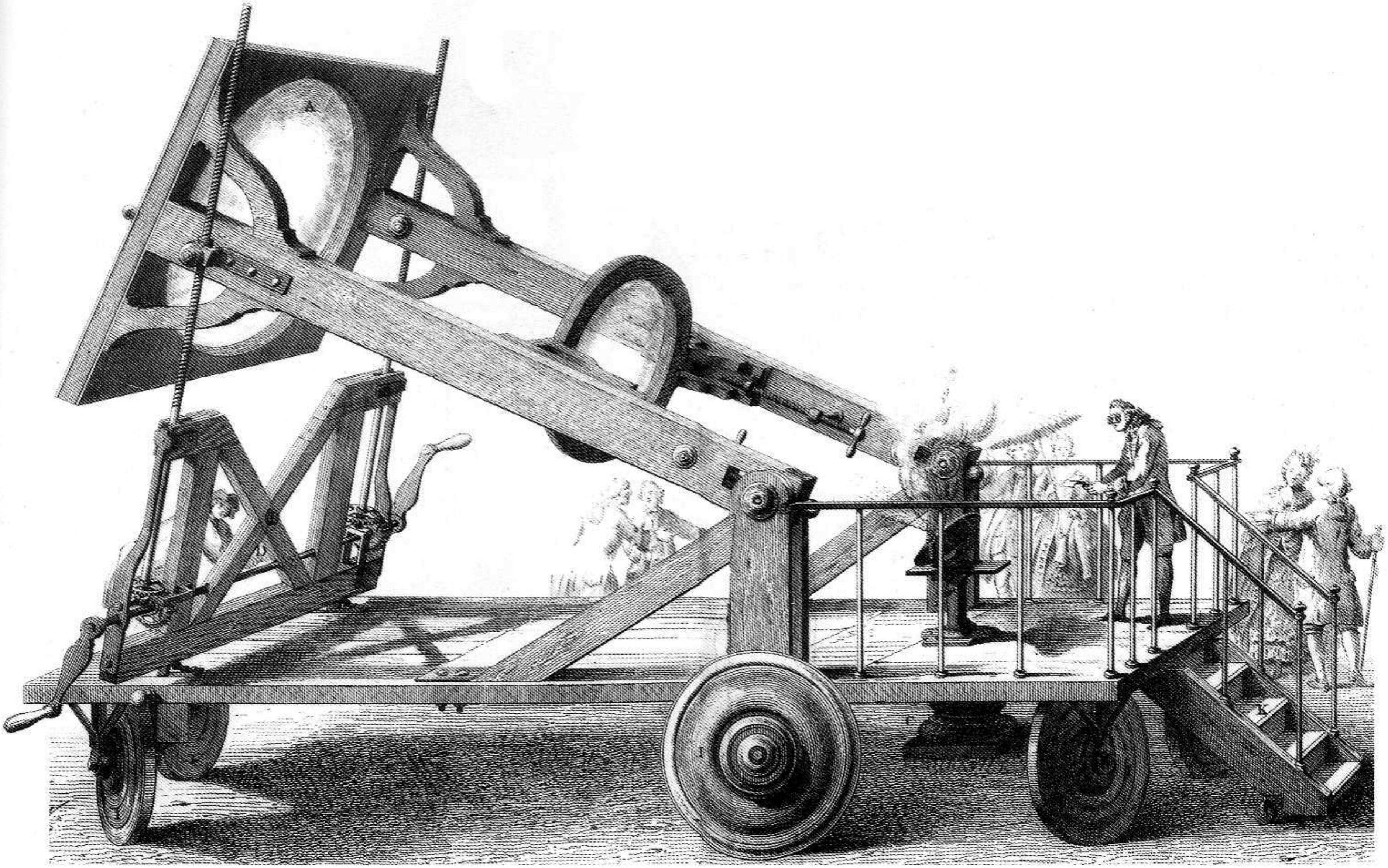
1. "Real Time" or "Un-accelerated"
2. Moderately Accelerated
3. Ultra-Accelerated

Ultra-Accelerated (UA)

- The trick is <u>not</u> that we can expose the specimens to ultra high irradiance…anyone can do that!

Inverse Square Law Artificial Methods, High Intensity Artificial Light Sources, Natural Solar Concentrators

- <u>The trick is</u> that we can expose specimens;
  - 1)Under ultra high irradiance
  - 2)With ultra high fidelity to natural sunlight SPD
  - 3) Without the specimens melting or burning (thermal oxidation).



EWS Budapest

Ultra-Accelerated Weathering System I: Design and Functional Considerations, Hardcastle, Jorgensen, Bingham

(Presented at the 4th European Weathering Symposium, September 2009, Budapest, Hungary, Gesellschaft für Umweltsimulation, CEEES)

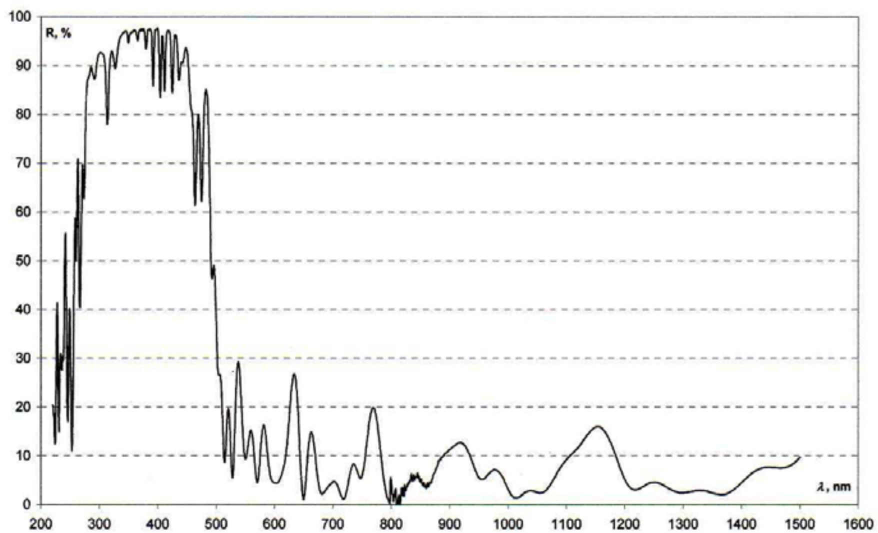
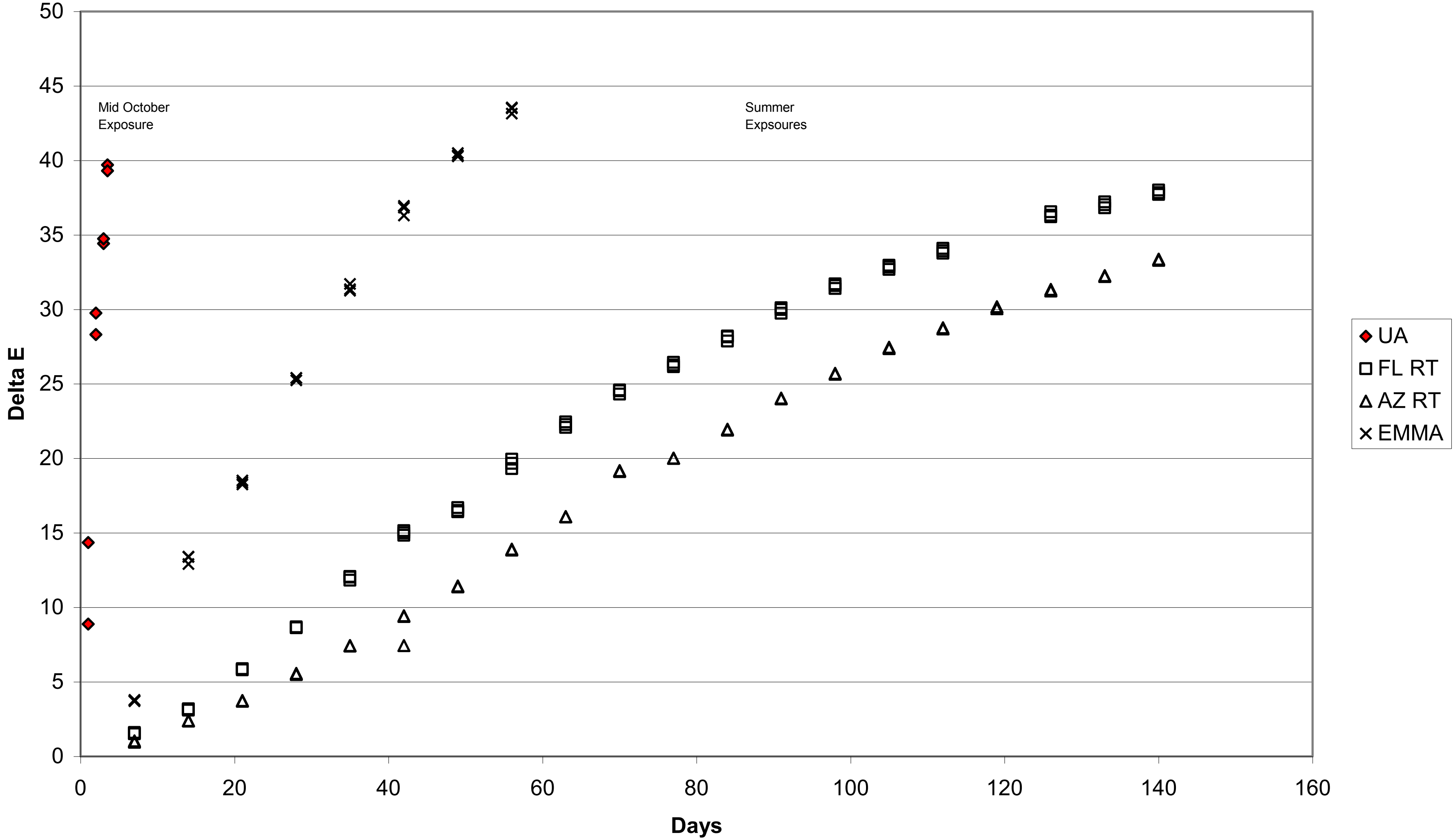


Fig. 7. Absolute reflectance plot for the facets Nos. 8/1 – 8/4.

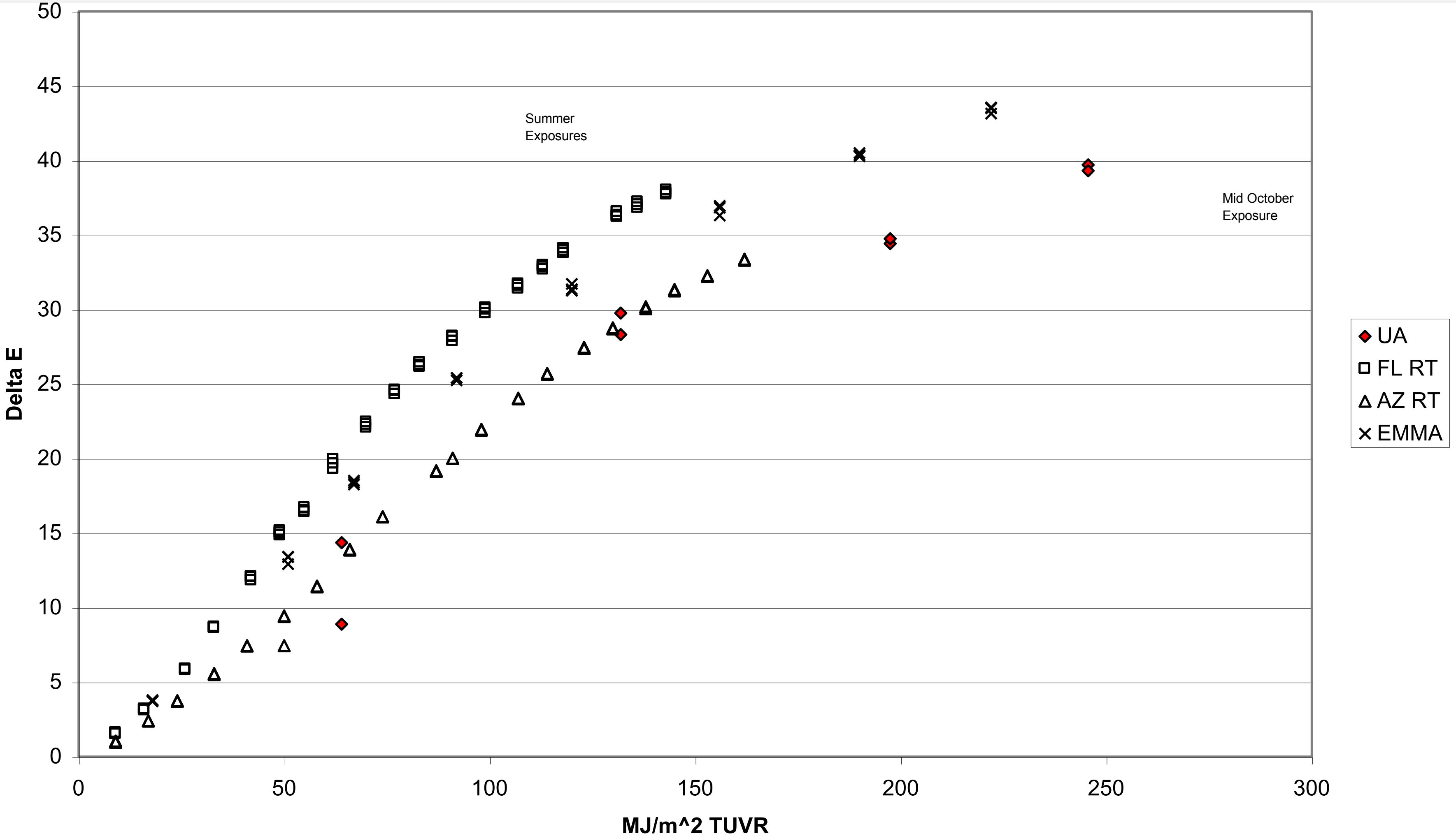
UAWS Results

- ORWET SRM
- Polystyrene SRM

Comparison of FL, AZ, EMMA and UA Exposures of ORWHET
By Days

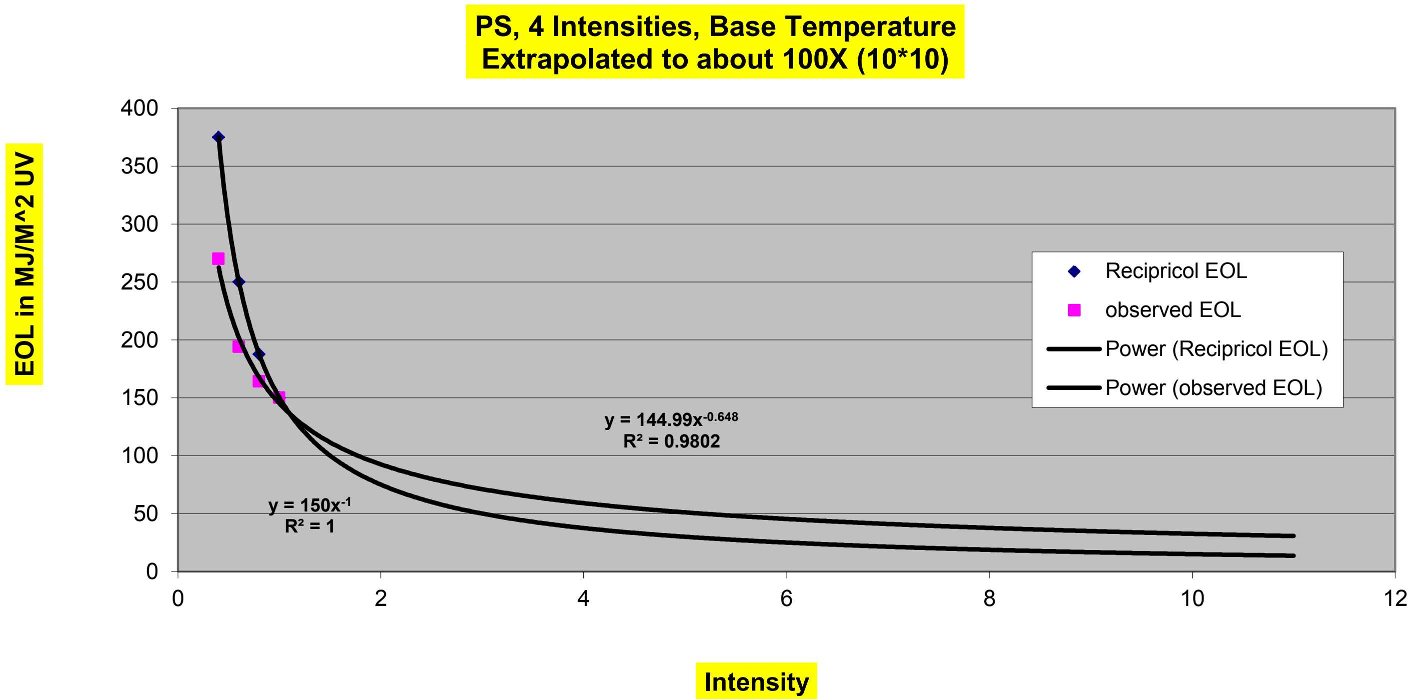


Comparison of FL, AZ, EMMA and UA Exposures of ORWET BY UV Radiant Exposure

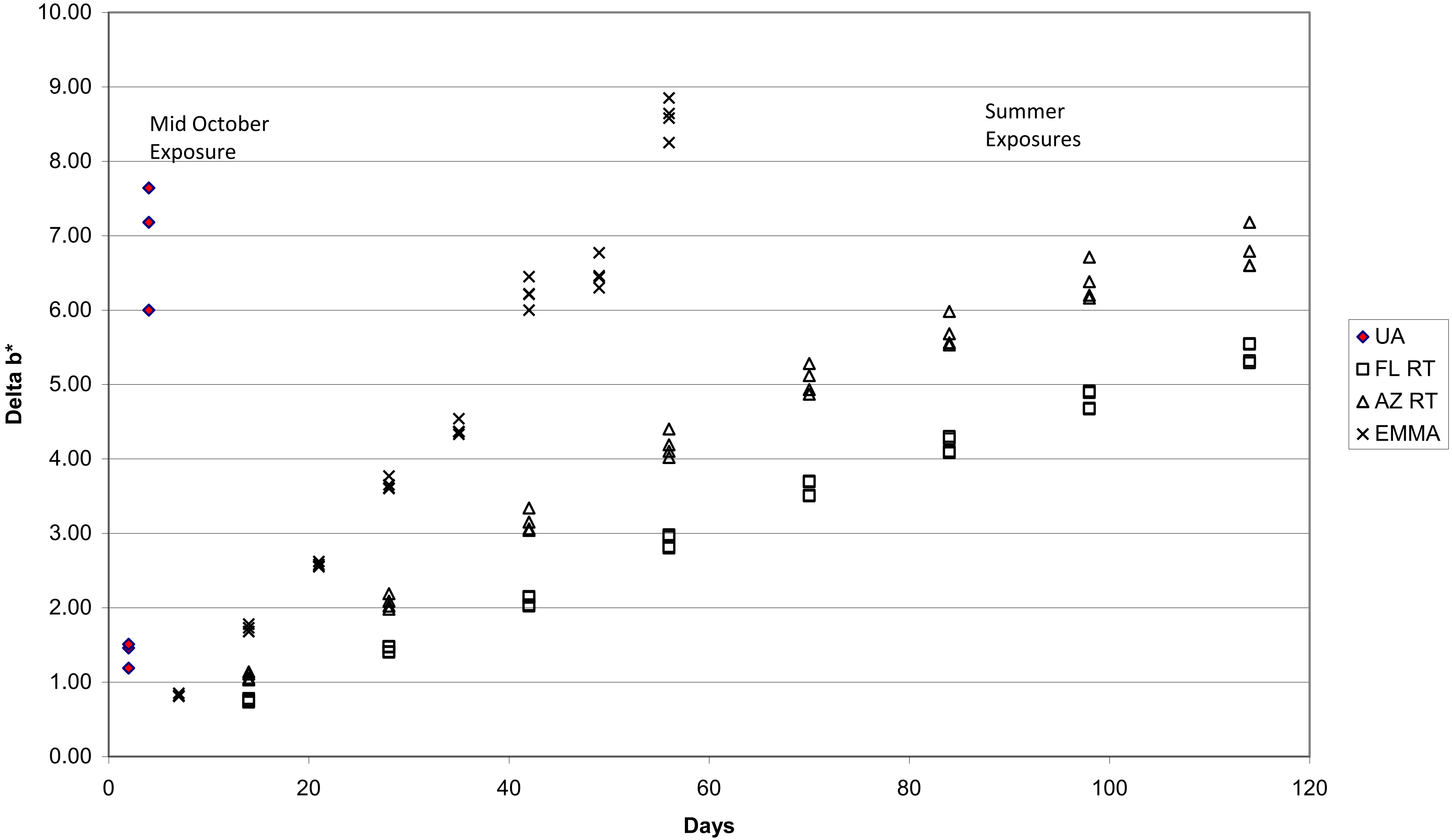


Testing The Sedona Hypothesis

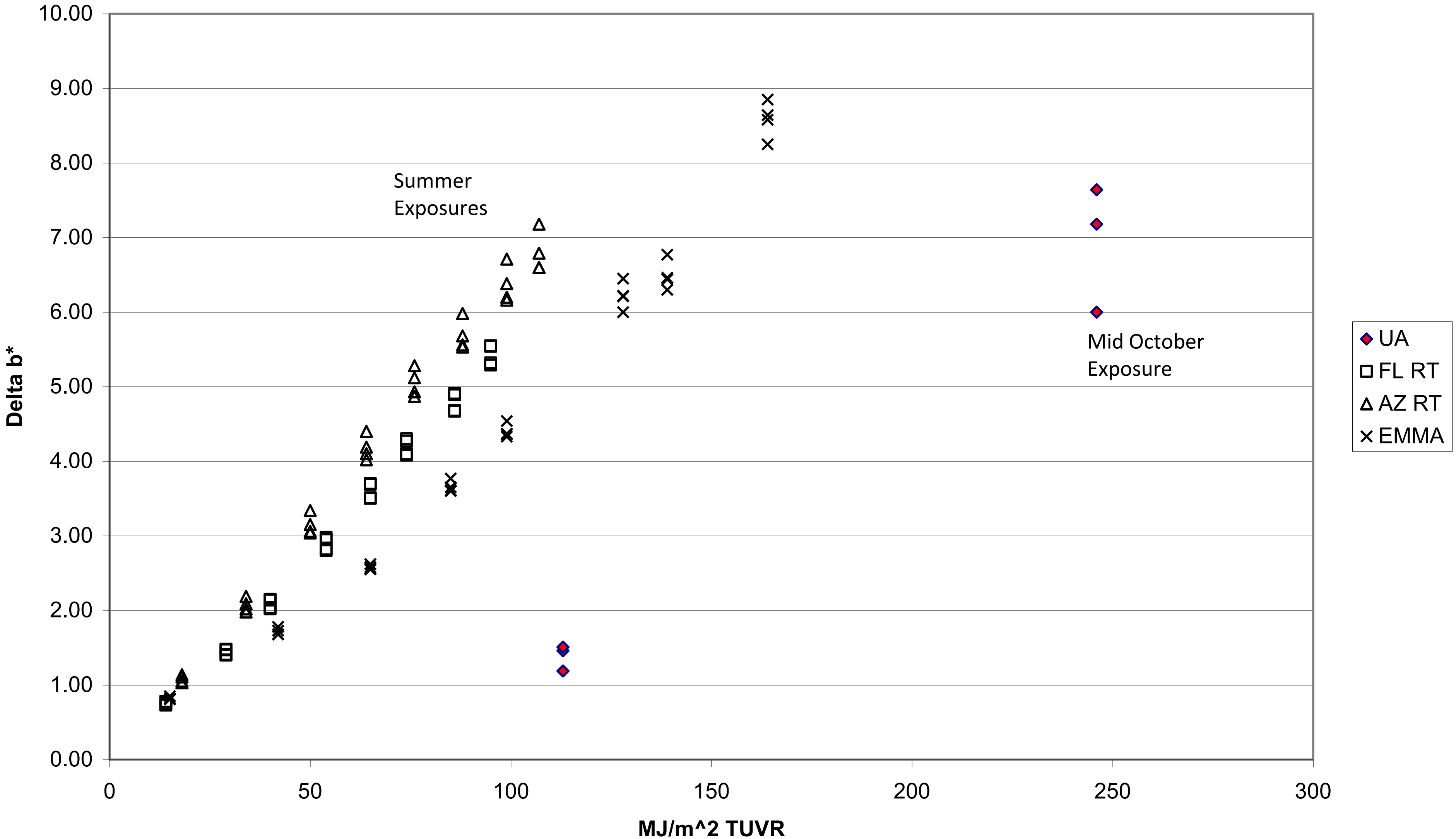
- Additional testing along the graph line shown at Sedona



Comparison of FL, AZ, EMMA and UA Exposures of Polystyrene By Days



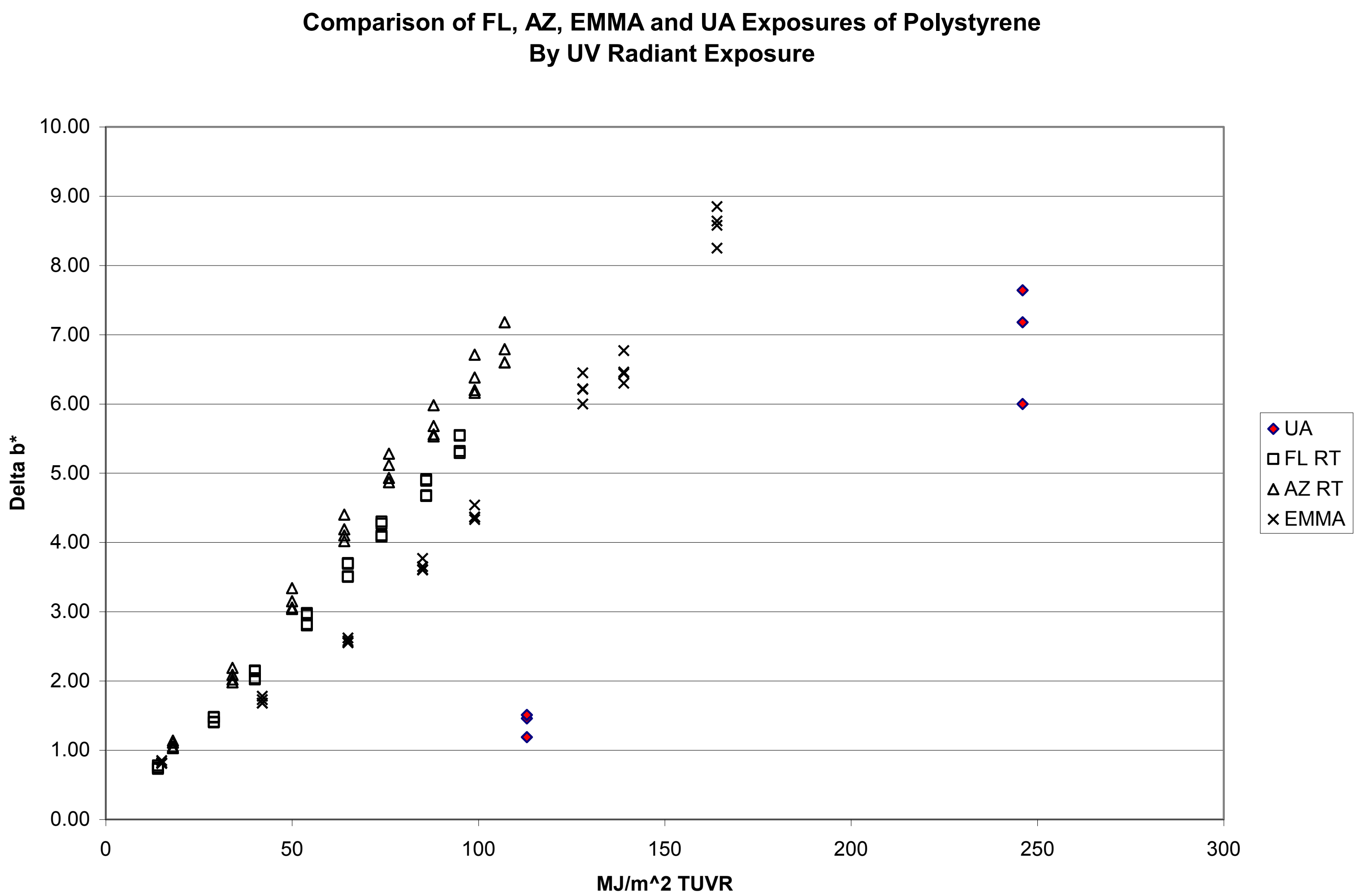
Comparison of FL, AZ, EMMA and UA Exposures of Polystyrene By UV Radiant Exposure



Implications

- Take Home Implications for SLP:
- Still very accelerated
- Very significant implications for accelerated SLP
- Timing of exposures based on MJ UV may not be a valid assumption
- Assumption of equivalence of effect of different intensities of UV may be erroneous for some materials
- So testing results at one intensity to a specific radiant exposure may differ significantly from testing results at a different intensity
- 308 MJ TUVR at 0.35 W/m^2 may yield different results than 308 MJ TUVR at 0.55 W/m^2

PS Characterizations in Outdoor Exposures



Testing The Sedona Hypothesis: Part II

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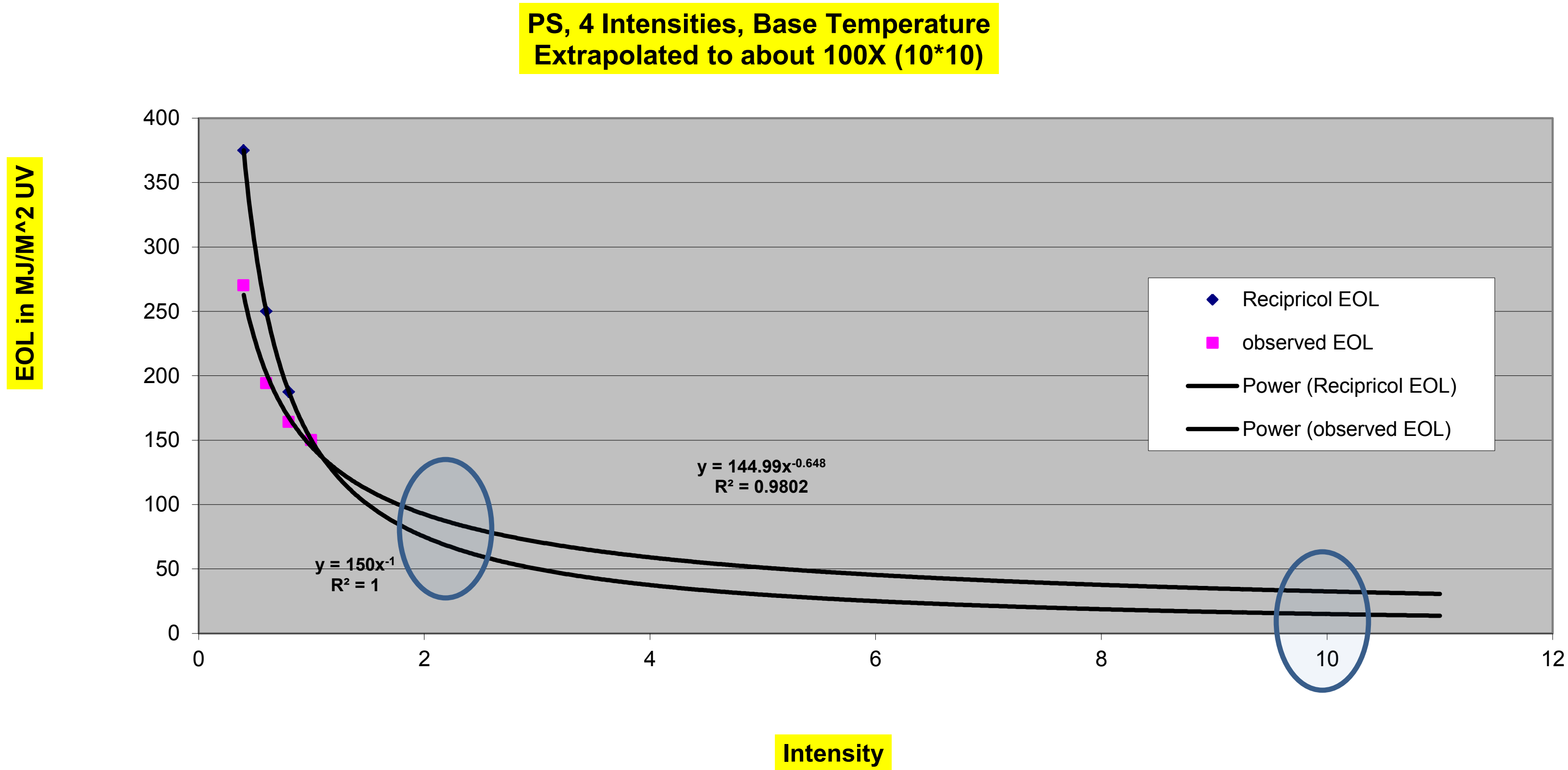
- The last slide I showed a hypothesis to test:



Ultra-Accelerated EMMA

- INTRODUCTION TO NEW DEVICE

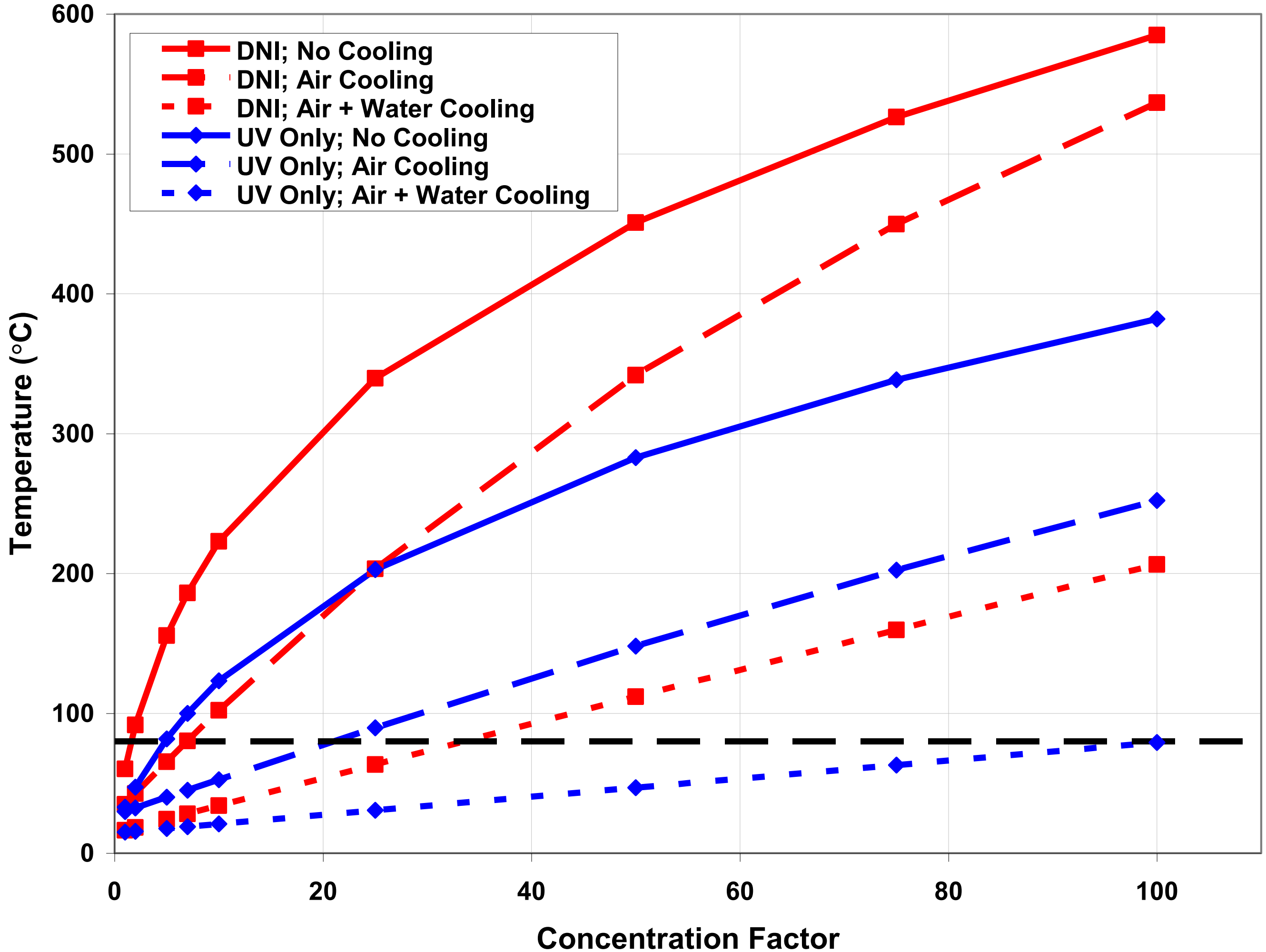
EMMA

- Existing EMMA
- Equatorial Mount with Mirrors for Acceleration
- ASTM G90

Temperature Constraint: Black Panel Temperature

ATLAS MATERIAL TESTING SOLUTIONS
AMETEK MEASUREMENT & CALIBRATION TECHNOLOGIES

- Energy Balance and EB prediction for EMMA



Ultra-Accelerated EMMA (UA EMMA)

- New Device Description
- Triple Constraints
- Parabolic Trough in
- 3 Dimensions
- Flat Mirrors

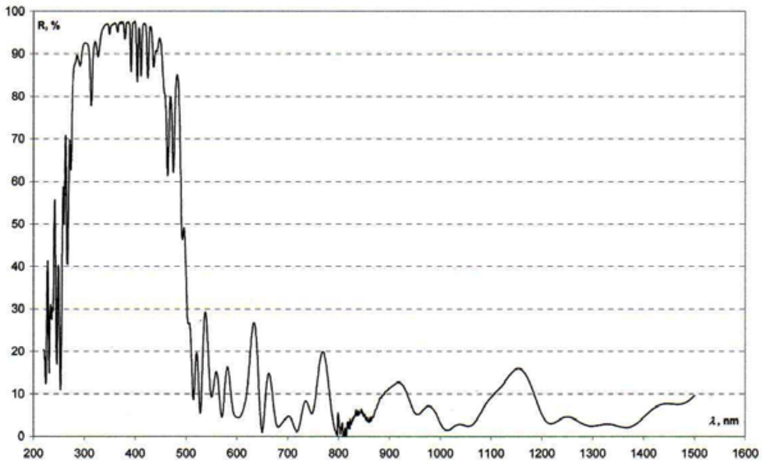
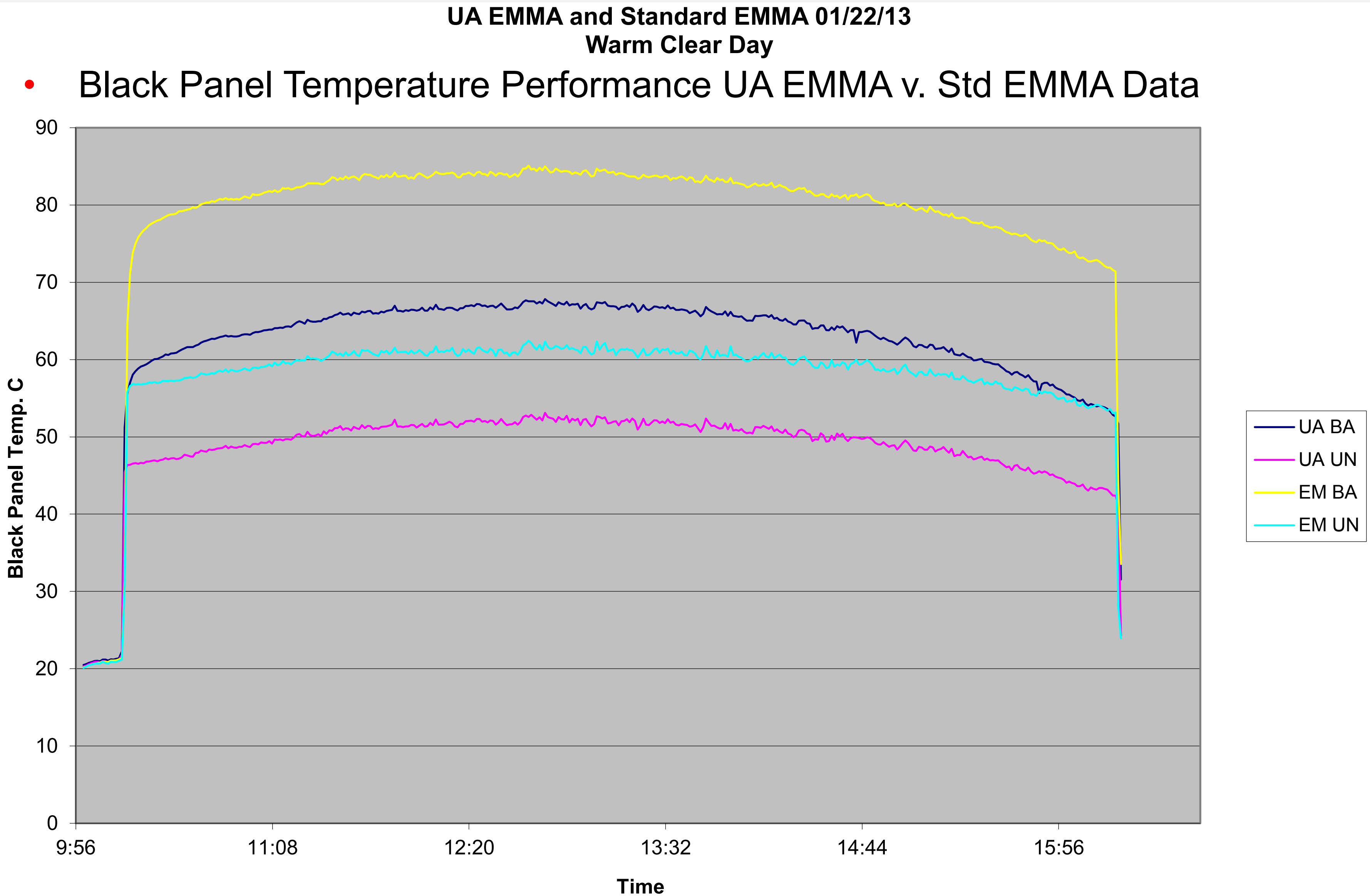


Fig. 7. Absolute reflectance plot for the facets Nos. 8/1 – 8/4.

Ultra-Accelerated EMMA

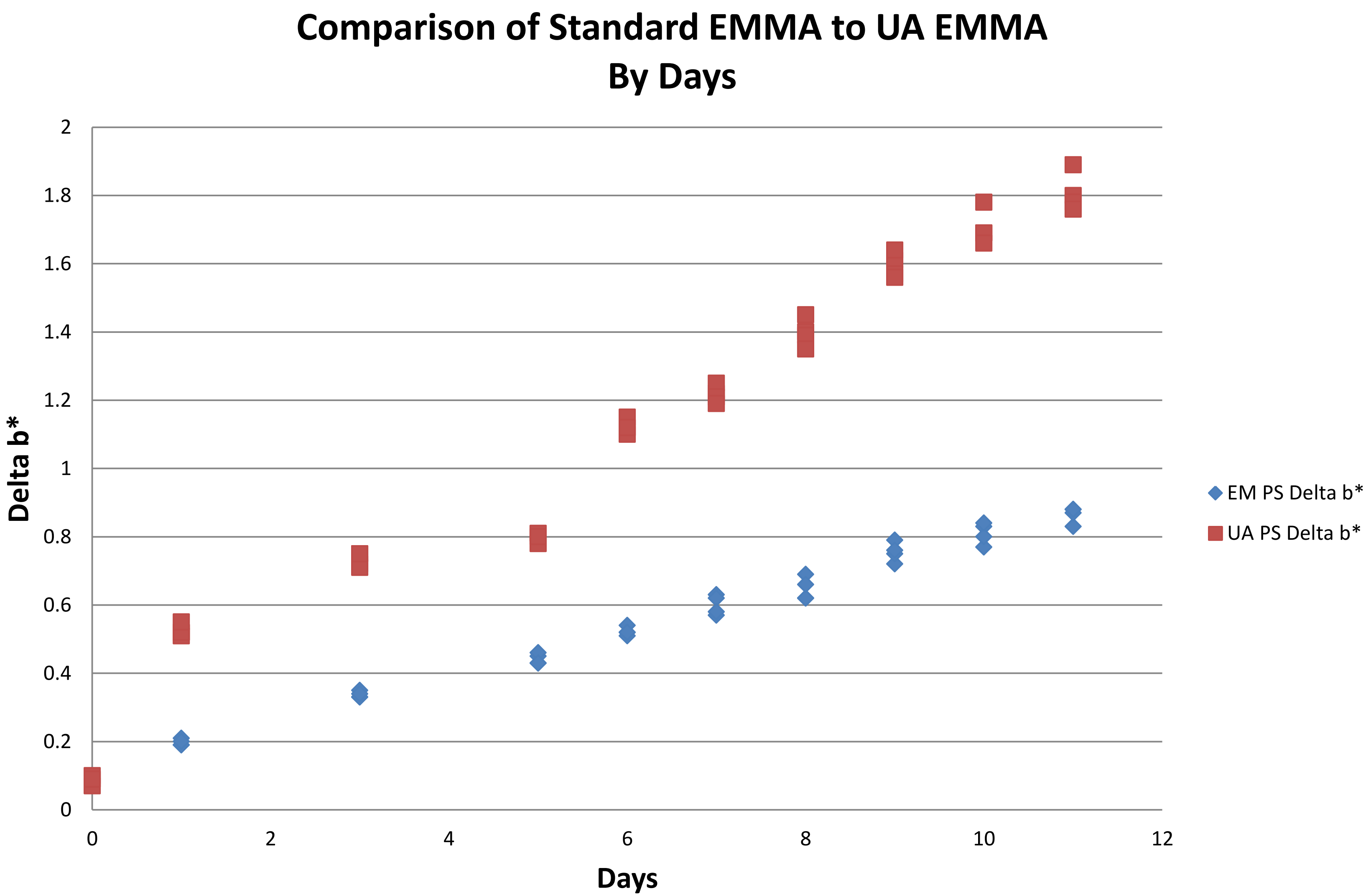
- Black Panel Temperature Performance UA EMMA v. Std EMMA Data



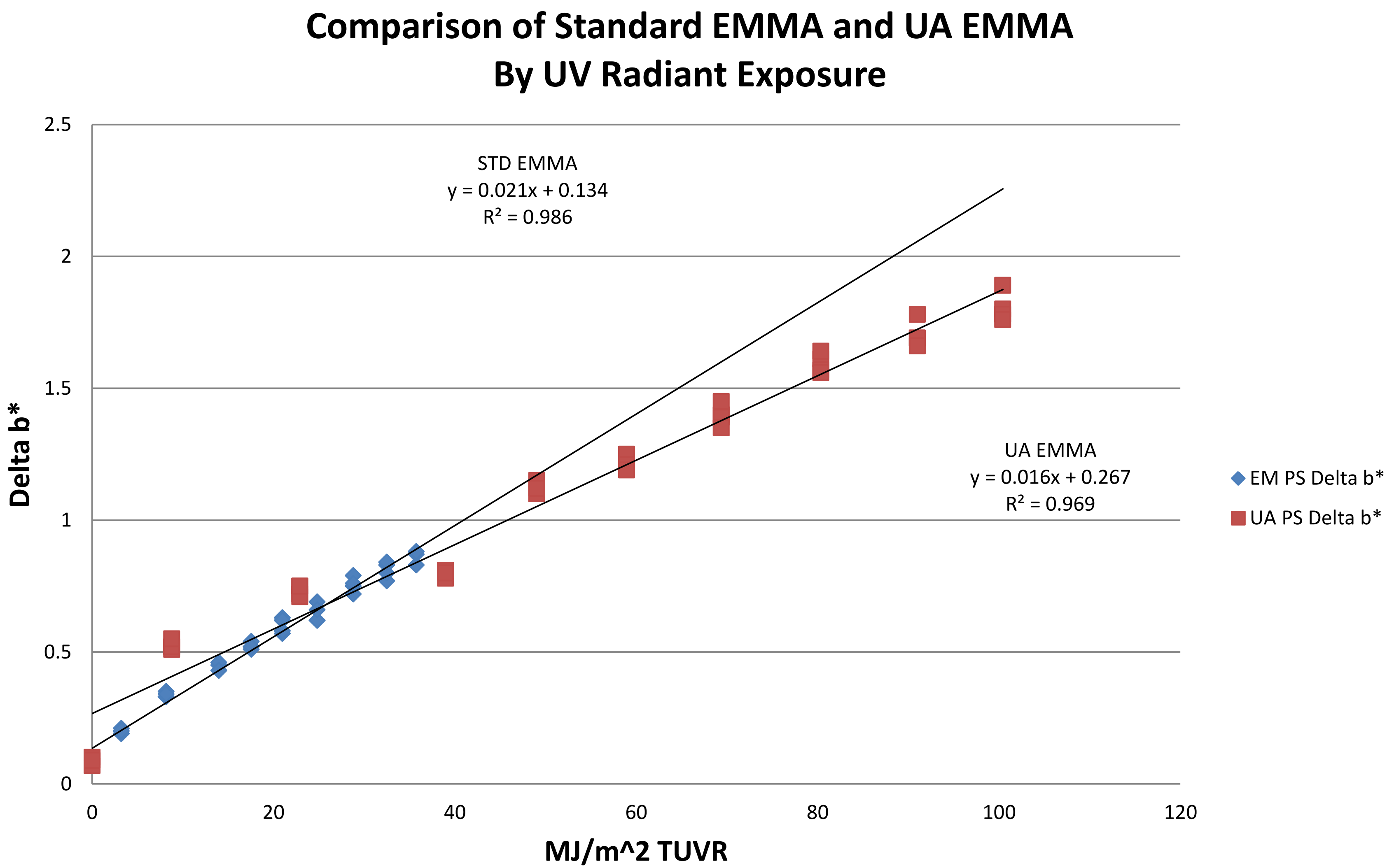
UA EMMA PS EXPOSURES

- February 2013
- Same Days, Side-by-Side
- 8 Mirrors on Standard EMMA
- 20 Facets on UA EMMA
- PS Exposure Temperature on UA EMMA Biased Higher by Approximately 5 Degrees C

UA EMMA PS Results

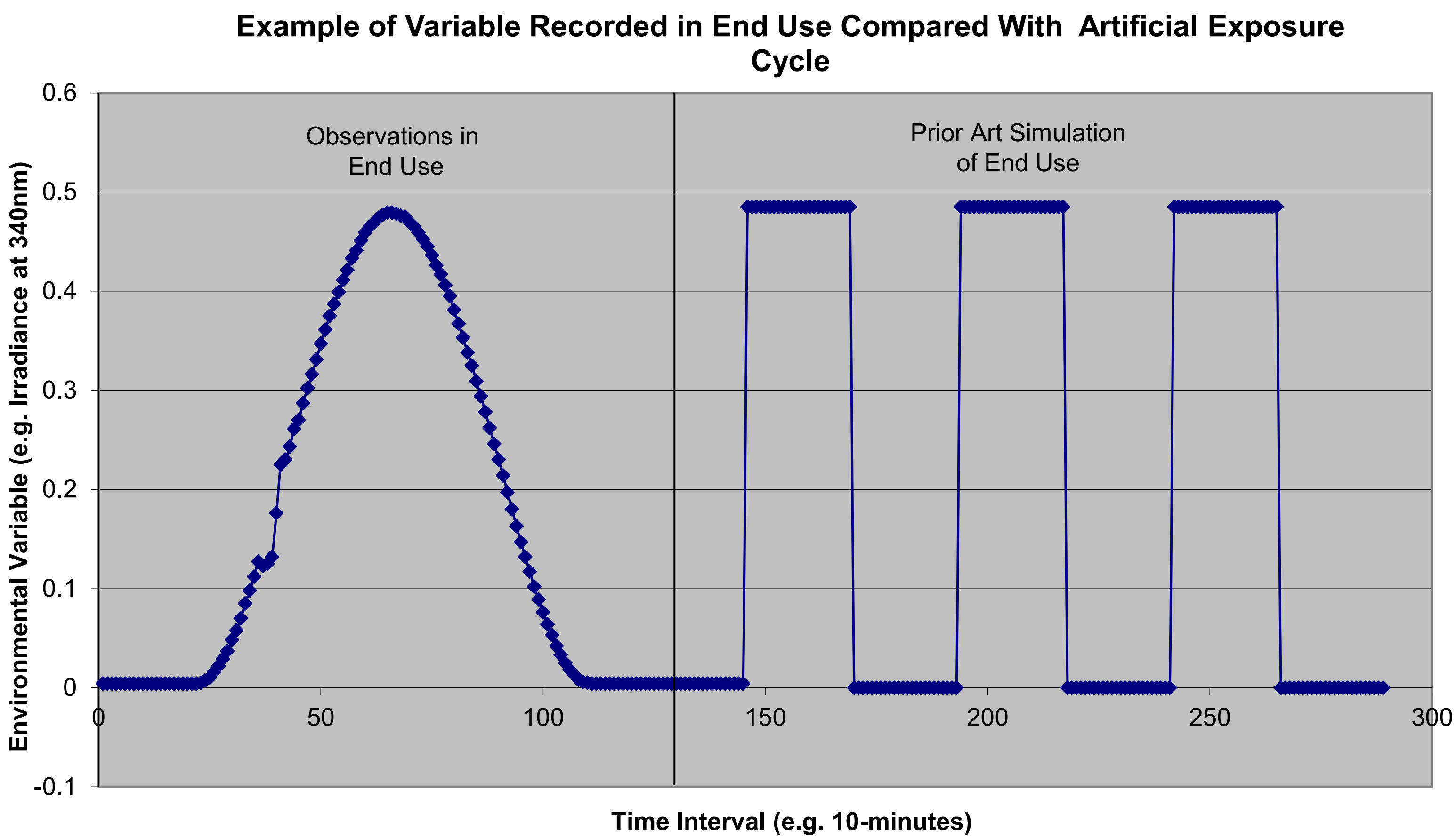


UA EMMA PS Results



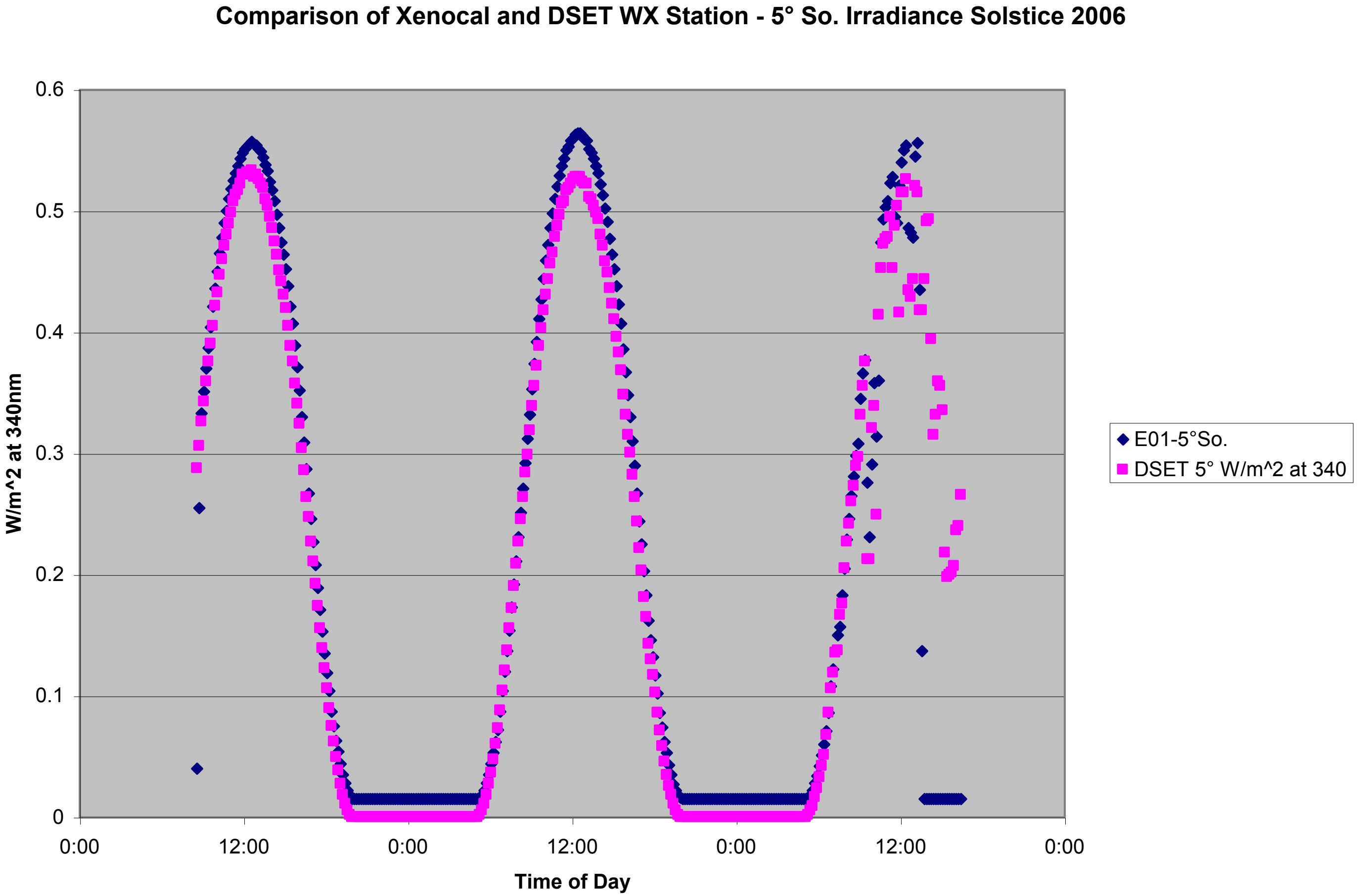
Take Home Implications II

- Low v. High Intensity
- Diurnal Cycle
- Steady State Lab Methods



Take Home Implications II

- Graph of Diurnal Cycle
- Intensity variation during day
- Intensity variation during clouds



Hypothesis for Next time

- Exposure to edited cycle parts
- Exact duplication of cycles measured outdoors
- Proper understanding and applications of stressor intensity may be critical for SLP for some materials
- Material dependency
- Skeletons along the SLP path

Testing The Sedona Hypothesis: Part III

- The last slide I showed a hypothesis to test:

PS, 4 Intensities, Base Temperature
Extrapolated to about 100X (10*10)