NREL
NATIONAL RENEWABLE ENERGY LABORATORY

IEC Quality Assurance Task Group 5: UV, Temperature, and Humidity

NREL PV Module Reliability Workshop

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Index #99, Wednesday, February 26, 4:40-4:50 pm
Golden, Colorado

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-this presentation contains no proprietary information-

Topics Covered Today

- Motivation: Goals and activities for QA TG5
- E_a interlaboratory experiment (TG5 US)
  - Motivation
  - Some details of the E_a experiment
- Timeline for TG5
- Mini-module experiment (TG5 Japan)
- SoPhia round-robin (TG5 Europe)

Goal and Activities for QA TG5 (UV, T, RH)

- IEC qualification tests (61215, 61646, 61730-2) presently prescribe up to 137 days field equivalent (IEC 60904-3 AM 1.5) UV-B dose
- Goal: develop UV- and temperature-facilitated test protocol(s) that may be used to compare PV materials, components, and modules relative to a field deployment.

Core Activities:

1: Study weathering and climates (*location-dependent information*).
   e.g., known benchmark locations…Miami, FL; Phoenix, AZ
2: Leverage existing standards, including other industries.
   √ summary exists from Kurt Scott *et al.*
3: Improve understanding of existing PV UV tests.
4: Improve understanding of module durability.
   4-1 Collect information about observed failure modes.
   e.g., the literature, site inspections
   4-2 Confirm appropriate models for aging.
5: Verify suitable UV sources.
   √ summary of *module* capable equipment from David Burns *et al.*
6: Generate protocol for accelerated service testing.
7: Perform laboratory verification of proposed test standard/failure mode.
   mini-module study, SoPhia round-robin, E_a interlaboratory study

Motivation for the E_a Interlaboratory Experiment (TG5 US)

- Knowing E_a (for rate of change in a characteristic) is critical to prescribing and interpreting a *UV- and temperature*-mediated test.
- Unfortunately, E_a is not known for the common UV-related PV degradation modes.

$$k = A\left[\frac{T}{T_0}\right]^n e^{\left[\frac{-E_a}{RT}\right]}$$

The modified Arrhenius equation

Critical unknowns
(Goals for the interlaboratory experiment):

1. Quantify E_a so that applied test conditions can be interpreted.
2. Provide a sense of the range of E_a that may be present by examining "known bad," "known good," and "intermediate" material formulations.
3. Determine if there is significant coupling between relevant aging factors, *i.e.,* UV, temperature, and humidity.
   What factors does TG5 need to consider?
4. Investigate the spectral requirements for light sources by comparing E_a for different sources, *i.e.*, Xe-arc, UVA 340.
   Is visible light required in addition to UV light?

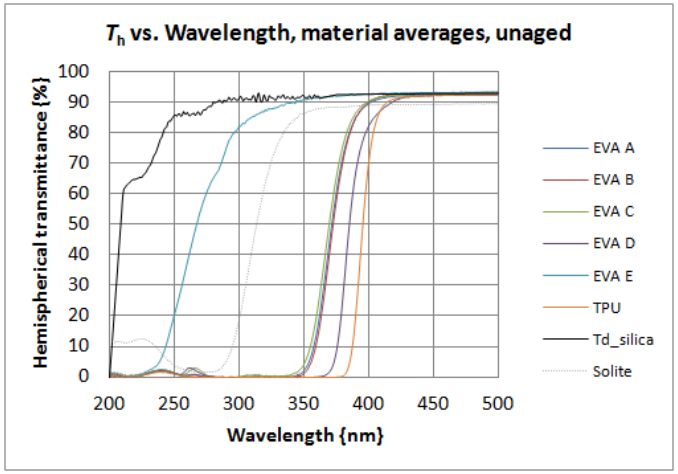
Some Details of the E_a Methods and Experiment

Optical transmittance:

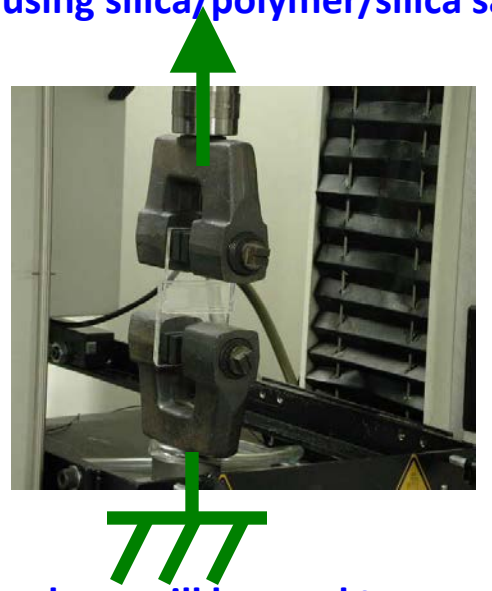
- (5) EVA + (1) TPU in encapsulation transmittance study.
- (10) intermittent measurements will be performed.

Mechanical attachment:

- (1) EVA will be examined using the compressive shear test.
- (2) edge seals will be examined using shear and wedge tests.
- (5) intermittent measurements will be performed.



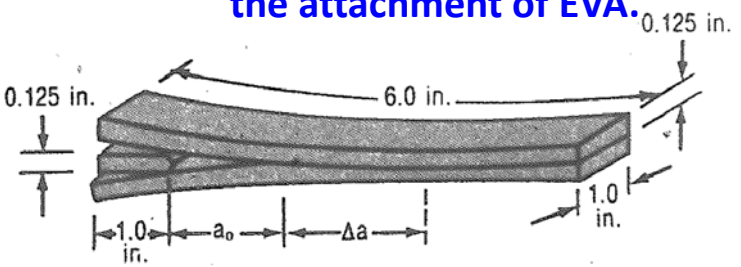
Transmittance will be examined using silica/polymer/silica samples.



Overlap shear will be used to examine the attachment of edge seals.

Photo courtesy Kempe *et al.*

The CST will be used to examine the attachment of EVA.



A DCB wedge test will be used to examine the attachment of edge seals.

Marceau *et. al.*, Adhesives Age, 1977, 28-34.

The E_a Interlaboratory Experiment Enables a Wider Range of Study

- Discoloration and adhesion will be studied in detail at different institutions using the same make and model of instrument (*i.e.*, Ci5000, QUV).
- This overcomes the difficulty of limitedly available aging equipment.

- A standard condition (60°C in chamber) allows a broad variety of other instruments (light sources) to also be compared.

LIGHT SOURCE, FILTER	Xe Arc (right-light/cira filter) or (Suga-Q/#295/Ircut)					UVA 340 fluorescent (no filter)		UVA 340 fluorescent (no filter)	No light			field deployment (outdoors)
UV LIGHT INTENSITY	NOMINAL (102 W•m^{-2} for 300≤λ≤400)					NOMINAL (1.0 W•m^{-2}@ 340 nm)		NOMINAL (~150 W•m^{-2} for 300≤λ≤400)	0 W•m^{-2}			
CHAMBER RELATIVE HUMIDITY {%}	30 ("low")			50 ("high")		~7% ("very low")		60 ("high")	30 ("low")			ambient
CHAMBER TEMEPRATURE {°C}	40	60	80	40	60	40	60	60→ 80 → 40	40	60	80	ambient
PARTICIPANT (INSTRUMENT MODEL)	3M (Ci5000)	3M (Ci5000)	3M (Ci5000)	Mitsui (SX120)	NREL (Ci5000)	QLAB (QUV)	QLAB (QUV)	Fraunhofer (custom)	NIST (custom)	NIST (custom)	NIST (custom)	ATLAS (EMMA in Phoenix)
		QLAB (QSUN XE3)			QLAB (QSUN XE3)	ATLAS (UVTEST)	NREL (custom UV suitcase)					CWRU (5x in Cleveland)
		ATLAS (SunTest XXL)					Fraunhofer (customized)					ATLAS (rack in Phoenix)
		Suga (SX75)					Suga (FDP)					ATLAS (rack in Miami
							CWRU (QUV) @1.55 W·m-2 @ 340 nm					NREL (rack in Golden)

Summary of participating laboratories and test conditions

- Rate of degradation will be compared against field data to allow site-specific acceleration factors to be determined.
- Outdoor data will verify validity of the test.

- Separate experiment at NIST (same EVA's) will determine action spectrum.

Timeline and Goals for TG5

	Qualification	QMS	Comparative Rating	Service Life Prediction
Current status	Issued as standards	Revised NWIP submitted	Proposed as concepts	Concepts
2014 goal	Submit Ed 3 61215 Ed 2 61730	Publish new TS	Initiate E_a test. Create strawman UV standard.	Develop criteria to evaluate QMS related to service life; NWIP
2015 goal	Publish new editions	Start use of the TS in factory inspection	Submit UV standard NWIP. Create strawman test sequence standard. Complete E_a test.	
2016 goal		Revise QMS document to reflect feedback	Publish E_a results. Submit CD UV standard.	
Chamber test times	Modules: ~ 6 weeks	TBD	~6 months	~18 months

The Mini-Module and SoPhia R-R TG5 Experiments

Mini-Module Experiment (TG5 Japan)

- Examines module performance (I/V), encapsulation durability, and backsheet durability after aging (UV, T, %RH).
- UV exposure can affect results of other tests, i.e., DH and TC.
- Will be examining adhesion within PV modules.
- See also PVMRW 2014 poster (index #85) by Shioda *et al.*

SoPhia R-R (TG5 Europe)

- Samples (7) backsheet vendors at (7) test labs.
- Examines light sources (fluorescent, metal-halide, xenon) using 3 long-pass and 2 neutral-density filters.
- Examining test temperature (60°C and 80°C used in experiment).
- Refer to future work of Köhl *et al.*

Acknowledgements

- There has been fantastic participation in TG5.

  Thank you - to the many participants!
- If interested in TG5 or the experiments, please contact the corresponding regional TG5 leader. (See title slide)
- Let me know if you are interested in any of the related material standards? (encapsulation transmittance, encapsulation adhesion, edge-seal attachment)
- TG5 dinner meeting

  Wednesday, 2/26, 6:15 pm at

  Mimi's Café (14265 W Colfax Ave)

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NREL STM campus, Dennis Schroeder