



Progress in IEC PV Component Weathering Standards

Nancy Phillips

December 6, 2017

DuPont Photovoltaic Solutions

For over 40 years

our material innovations have led the photovoltaics industry forward, and helped our clients transform the power of the Sun into power for us all. Today we offer a portfolio of solutions that deliver **proven power and lasting value** over the long term. Whatever your material needs, you can count on quality DuPont Photovoltaic Solutions to deliver the performance, efficiency and value you require, day after day after day...



Outline

- Importance of component weathering
- Component testing in IEC standards
- IEC 61730-1 AMD1, Backsheet Weathering Requirement
- IEC 62788-7-2 TS: PV Component weathering
 - Status
 - Best practices
- Component weathering – future focus

Importance of PV component weathering

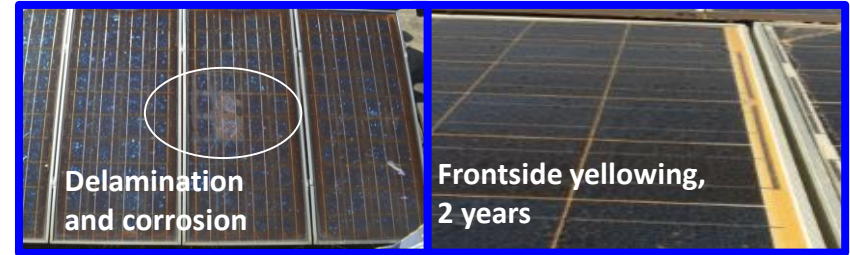
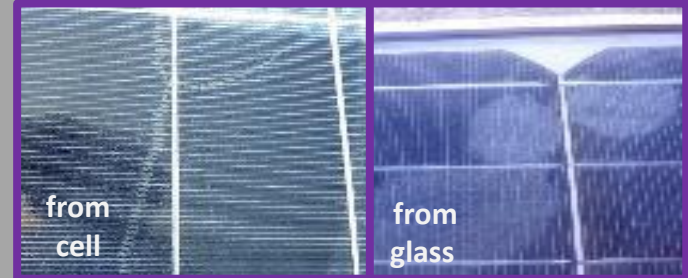
Degradation of components observed in the field

Observed failures can be screened out with standard component weathering tests

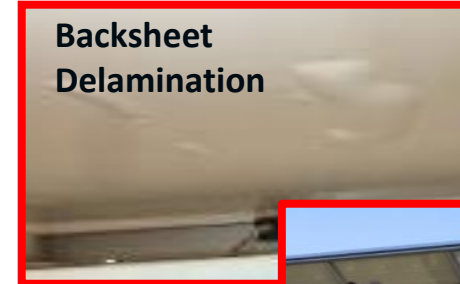
Component weathering allows for

- More samples
- Longer exposures
- More informative tests

Encapsulant Delamination

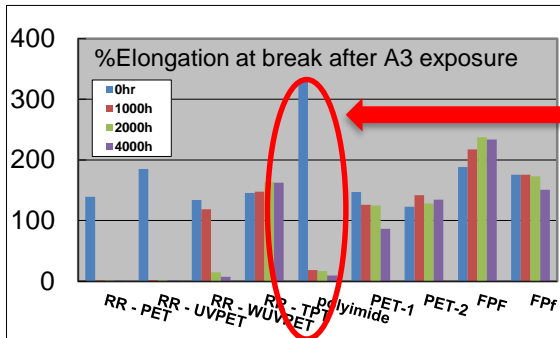


Backsheet Delamination



Backsheet cracking
4 years, Italy

Backsheet yellowing
4 years



Component Testing in IEC Standards: IEC 62788 series: Measurement procedures for materials used in photovoltaic modules

Intended use:

- Standardized approach to Supplier Data Sheets
- Test methods for research— understanding impact of components on module performance
- Reference by other standards

Structure:

- Some individual test methods
- Some compendium of test methods, with “data sheet”

PROJECT	TITLE	STATUS
IEC 62788-1	Encapsulants	
-1	Polymeric materials used for encapsulants - data sheet	Draft
-2	Volume resistivity	Published
-4	Optical transmittance	Published
-5	Change in linear dimensions	Published
-6	EVA degree of cure	Draft
-7	Test procedure for the optical durability of transparent polymeric PV packaging materials	Draft
IEC 62788-2	Frontsheets and Backsheets	Published
IEC 62788-5	Edge Seal	
-1	Edge Seal test methods	Draft
-2	Edge-seal durability evaluation	Draft
IEC 62788-6	General Tests	
-2	Moisture permeation testing with polymeric films	Draft
-3	Adhesion testing of interfaces within PV modules	Draft
IEC 62788-7	Environmental Stress Tests	
-2	UV weathering of PV polymeric components	Published

New Work Item: 62788-8-2 , Abrasion tests

IEC 62788-2 TS Table 3 – Uniform characterization form (UCF) for polymeric PV frontsheet or backsheet

UCF No.	test name	reference	fresh	1 000 h DH test (4.10.2)	2 000 h UV (Xenon) test (4.10.3) with exposure of	
					air side ^a	sun-facing side ^b
1	dimensions and tolerances [μm]	4.2.2	✓	–	–	–
2	area weight and tolerances [g/m ²]	4.2.3	✓	–	–	–
3	a) tensile strength [MPa] (MD)	4.2.4	✓	✓	✓	✓
4	b) tensile strength [MPa] (TD)	4.2.4	✓	✓	○	○
	a) elongation at break [%] (MD)	4.2.4	✓	✓	✓	✓
	b) elongation at break [%] (TD)	4.2.4	✓	✓	○	○
5	bond strength between layers of composition – or weakest link [N/mm] (for peelable layers)	4.3.6.2	✓	✓	○	○
6	bond strength between coatings or thin layers and film [rating scale] (for layers too thin or brittle to peel)	4.3.6.2	✓	✓	○	–
7	bond strength between a specific encapsulant and sheet [N/mm]	4.3.6.3	○	○	○	○
8	bond strength between a specific junction box adhesive and sheet [N/mm]	4.3.6.4	○	see IEC 62790	–	–
9	RTE/RTI/TI [°C]	4.4.1	✓	–	–	–
10	dimensional stability in MD & TD [%]	4.4.2	✓	–	–	–
11	relative thermal expansion [K ⁻¹]	4.4.3	○	–	–	–
12	dc breakdown voltage [kV]	4.5.1	✓	○	○	○
13	distance through insulation [μm]	4.5.2	✓	–	–	–
14	comparative tracking index (CTI)	4.5.3	✓	–	–	–
15	visual inspection	4.6.2	✓	✓	✓	✓
16	solar transmittance (for transmittive sheets only)	4.6.4	✓	○	○	○
17	solar reflectance c (for reflective sheets only)	4.6.5	✓ (sun-facing)	○ (sun-facing)	–	○ (sun-facing)
18	yellowness index DYI c	4.6.6	○	○	○ (air side)	○ (sun-facing)
19	CIE L*a*b* (D65/10°) c	4.6.7	○	○	○ (air side)	○ (sun-facing)
20	specular gloss c	4.6.8	○	○	○ (air side)	○ (sun-facing)
21	water vapour transmission rate [g/m ² d]	4.7.1	○	–	–	–
22	resistance to recommended cleaning solvent	4.8.1	○	–	–	–

IEC 62788-7-2 TS: PV component weathering

Status

Published 2017 !

Includes:

Menu of weathering exposure conditions

Descriptive options for test specimens

Informational annexes

- Characterizing the conditions of polymeric components in fielded modules
- Development of the test methods in this document and recommendations for use

METHOD A: Xenon lamps				
optical filters as in ASTM D7869				
#	Chamber air temperature °C	Black panel temperature °C	Irradiance W/(m ² ·nm) at 340 nm	Relative humidity %
A1	45	70	0,8	20
A2	55	80	0,8	20
A3	65	90	0,8	20
A4	75	100	0,8	20
A5	85	110	0,8	20 (nominal)

METHOD B: Fluorescent UVA-340 lamps				
	Black panel temperature °C	Chamber temperature °C	Irradiance W/(m ² ·nm) at 340 nm	Relative Humidity %
B1	55	Not specified	0,80	Typically not controlled
B2	65		0,80	
B3	75		0,80	
B4	85		0,80	
B5	95		0,80	

Component weathering: alignment with other standards

Current (published, developing):

- Other component standards
- Related to module safety – material relied-upon for insulation should be durable
- Related to module performance – material in the light path of the cell should maintain transparency

In discussion:

- Qualification of extensions to module design (equivalent BOMs)
- Long term reliability analysis

62788-7-2 Component Weathering Exposures

	Chamber Air T (°C)	Black Panel T (°C)	Irradiance (W/(m ² ·nm)) @ 340 nm	RH (%)
A3	65	90	0,8	20

62788-n

Property Evaluation Methods

Reference 62788-7-2 for exposures

- 1: Encapsulants
- 2: Backsheets
- 5: Edge Seals

61730 AM1 Module Safety (Committee Draft)

Frontsheet/Backsheet Weathering Pass/Fail Requirements

Reference 62788-7-2 (exposures)

Reference 62788-2 (test methods)

61215 PV Module Performance (Future version)

Frontsheet/Encapsulant Weathering Pass/Fail Requirements

Reference 62788-1-7 (durability evaluation)

Reference 62788-7-2 (exposures)

Reference 62788-1-4 (test method)

63126 PV Modules – High T operation (NP)

Stress exposures at higher T

IEC 61730-1 AMD 1, Backsheet weathering requirement

Status: Committee Draft circulating in IEC

Specimen Exposures

- Sun-facing side exposed specimens
 - Visual inspection
- Air-facing side exposed specimens
 - Visual examination
 - % Elongation

Laboratory Weathering

- Exposure conditions
 - Frontsheets and white / clear backsheets: A3 (65C/90C ChT/BPT)
 - Black or coloured backsheets, A2 (55C/90C ChT/BPT)
- Exposure time:
 - 2000 hours
 - additional set: 4000 hours if using the alternate pass/fail criteria.

Ongoing Discussion Topics

Aiming for resolution by April 2018

- Exposure ChT/BPT: (A2 v. A3, or other) → compare to field results
- Exposure consistency
- % Elongation consistency
- Pass/fail criteria: minimum value after 2000 and 4000 hours, currently at 25% (absolute value)
- Specimen geometry for sun-side exposures
- Condition and duration of the optional thermal pre-conditioning step.

Pass/Fail Criteria

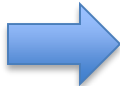
Test Method	Specimen	End-point Passing Criteria	Reference
Visual Examination (using front and back lighting)	Both sun-facing and air-facing specimens	No visual signs of degradation on sun-facing side or air-facing side when viewed under standard laboratory lighting and backlit lighting. No cracks, bubbles, or delamination	MST-01
% Elongation	Air-facing specimen	50% retention* after 2000 hours AND 25% minimum value, OR 25% minimum value after 4000 hours	IEC TS 62788-2

*Supplier may request preconditioning of the sample for up to 100 hours at up to 100 °C as requested by supplier (no additional humidity added)

Developing Best Practices for Consistency of Exposures

Research and Round Robin studies

- PVQAT TG 5X, Study #1: Encapsulants
- IEC Component Weathering: Backsheet RR Study
- PVQAT TG 5X, Study #2: Frontsheets/Encapsulants



Backsheet RR Study:

Target: A3 exposure consistency

- Experiment:
 - 9 Laboratories, devices from 3 different suppliers
 - 3 PETs with different expected durabilities, 1 BS
 - All samples measured at 1 laboratory
- Results:
 - test method consistency issues – confounds weathering consistency
 - Qualitative: fairly consistent, some outliers observed
- Follow-up analysis:
 - Survey of exposure conditions – weathering participants
 - Temperature survey

RR Exposure Data White PET after A3 exposures

Sample: Commercial white PET (WPET)

Exposure: 9 Different Laboratories, IEC 62788-7-2 A3

- 0.8 W/m²/nm@340 nm,
- ChT65C, BPT 90C, RH=20%

Evaluation Methods: (all at one laboratory)

Color (*b*^{*}) and IR:

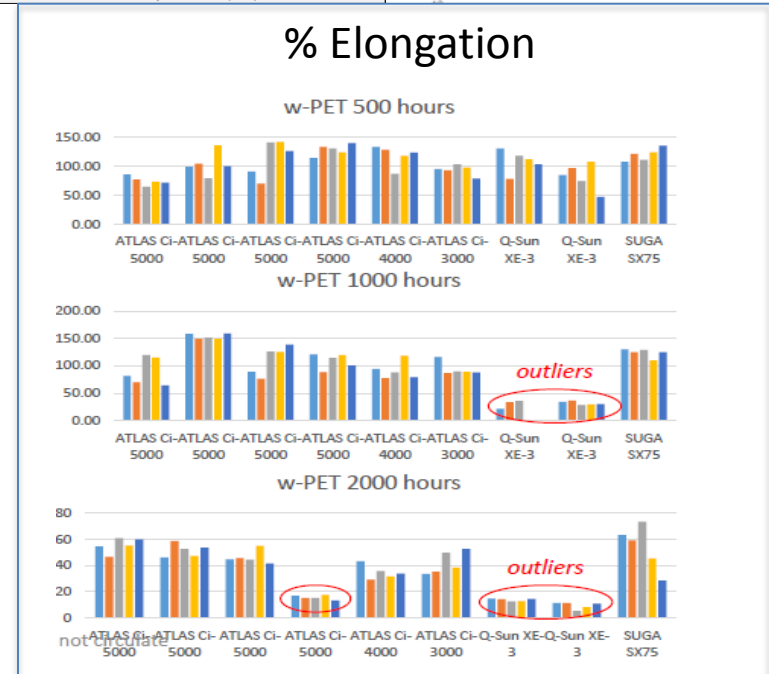
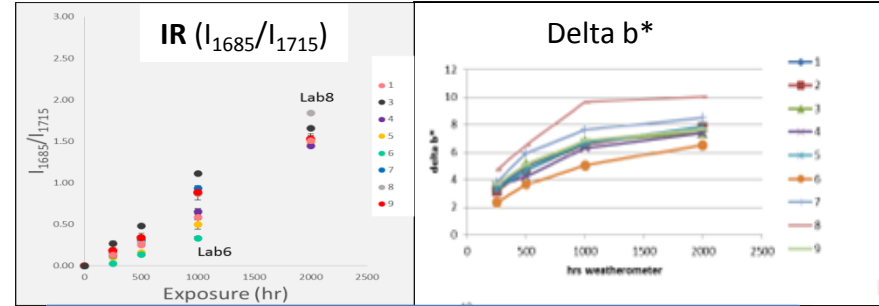
- Lab 8 results a little high, lab 6 a little low

Elongation:

- Variability in unweathered samples is high (next slide)
- Needs to be addressed – in progress
- Makes conclusions difficult → Qualitative analysis only
- 1000 H: 2 outliers (7, 8)
- 2000 H: 3 outliers (4,7,8)

Analysis *in progress*:

- Results: reasonably consistent with outliers removed
- Different metrics show different labs as outliers
- Different degradation modes activated by UV and heat; → IR, *b*^{*} are surface measures, % E is measures bulk
- Measured temperature differences do not correlate with outliers



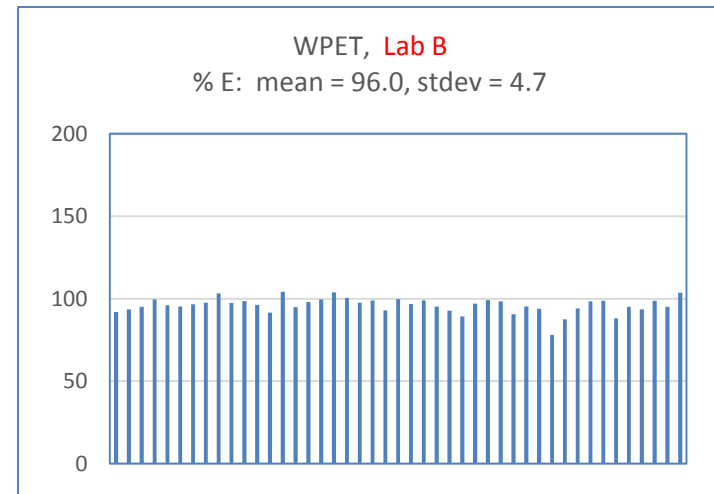
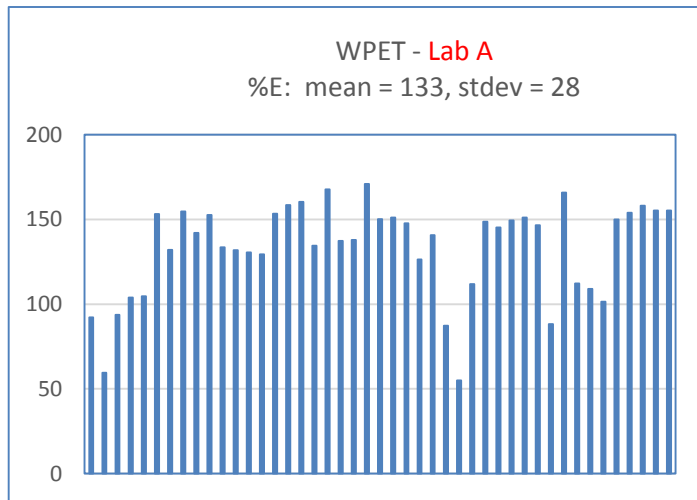
Test Method consistency

Elongation at break

WPET Data (unweathered)

- Lab A
 - Random samples
- Lab B
 - Cross-web samples

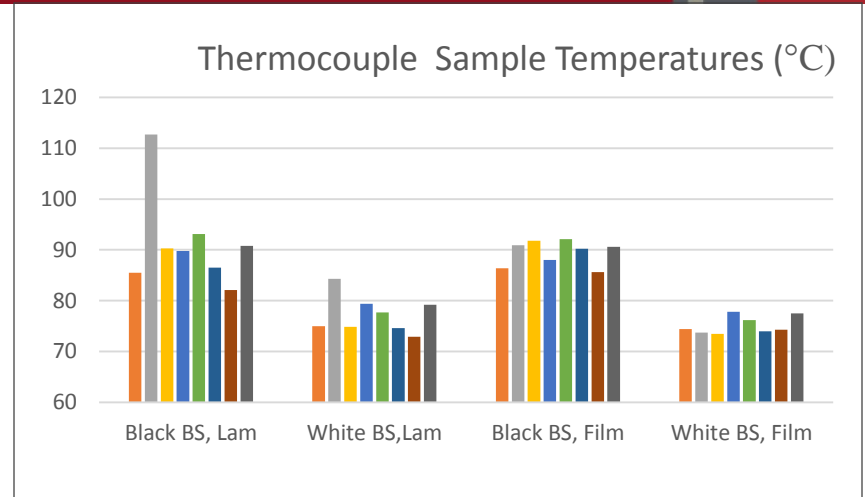
- Test method *can* be done with good repeatability
- Need to define Best Practices
 - Materials sampling, preparation, equipment, method, etc.



Temperature survey

Thermocouples still circulating

- White and Black Backsheets
- Free films and G/E/BS Laminates
- White film
 - Good consistency
 - Most relevant to RR
- Laminate samples
 - Outliers
 - Generally - consistent results between devices
- Outliers within same device set



lab		Black BS, Lam	White BS, Lam	Black BS, Film	White BS, Film
1	Atlas Ci4000				
2	Atlas Ci5000	85.5	75	86.4	74.4
3	Atlas Ci5000	112.7	84.3	90.9	73.7
4	Atlas Ci5000	90.3	74.9	91.8	73.5
5	Atlas Ci5000	89.8	79.4	88	77.8
6	Atlas Ci3000	93.1	77.7	92.1	76.2
7A	Q-Lab Q-Sun XE-3	86.5	74.6	90.2	74
7B	Q-Lab Q-Sun XE-3	82.1	72.9	85.6	74.3
8	Q-Lab Q-Sun XE-3	90.8	79.2	90.6	77.5
9	Suga SX75				
<i>1 standard deviation</i>		9	4	2	2

Survey of exposure details, BS RR study

Nominally: IEC 62788-7-2, A3

Questions in the following categories:

- Type of chamber
- Specimen fixture and mounting
- UV source
- Temperature Control
- Humidity verification

Differences:

- Fixed v. rotating rack
- Sample back: open, or on rack
- Optical filter (Boro/Boro v. RightLight/Daylight/Quartz)
- Black Panel (Insulated v. non-insulated)

NOTE: some of these are in the specification, but not clearly called out

Need to improve:

- Communicate standard practices
- Add additional "best practices"

Component weathering - future focus

PVQAT TG5x potential research topics

Standardized weathering exposures

- Define typical consistency between devices with A3 condition
- Develop “Best Practices”
- Exposures for High Temperature applications A4 or A5 (?) (IEC 63216)

Potential new exposures

Within the weathering device:

- Addition of water spray, and/or thermal cycling
- Similar to ASTM D7869 (light/dark; water spray, T changes)

Beyond the weathering device

- Thermal cycling, damp heat, ...


Test Methods

- Improved post-weathering evaluation test methods
- Weathering sample form factor
 - Polymeric package (v. component) testing
 - Backsheet specimens

Practical application/validation

- Comparing field/application/laboratory weathering
- More data on encapsulants, backsheets, and frontsheets

Future directions: applications of component weathering

- **62788-7** (Environmental stress protocols for polymer components)
 - Improved best practices
 - New weathering exposures
 - **62788-x** (Component test methods)
 - New test methods for weathered materials
 - **IEC 62915-?** Retest guidelines
 - Extension of module design qualification (alternate BOMs)
 - **IEC ?:** Data collection from extended stress testing of PV modules for risk analysis
- 

Preliminary draft, New Proposal (S. Kurtz)

This Technical Specification describes a consistent data collection methodology to identify photovoltaic module strengths and weaknesses by applying stresses and characterizing changes caused by those stresses. For some specific tests, coupons or minimodules may be most appropriate. This Technical Specification describes data collection rather than defining pass-fail criteria for issuance of a certificate. The data are designed for two primary purposes:

- Documentation of results of qualification testing such as those defined in IEC 61215 and IEC 61730 as a basis for evaluating adequate design qualification and type approval of terrestrial photovoltaic (PV) modules suitable for long-term operation in general open-air climates.
- Identifying variability in a module's response to long-term stress in order to assess the risk associated with variability of manufacturing or design.

www.photovoltaics.dupont.com

Copyright © 2017 DuPont or its affiliates. All rights reserved. The DuPont Oval Logo, DuPont™, The miracles of science™ and all products denoted with ™ or ® are registered trademarks or trademarks of E. I. du Pont de Nemours and Company or its affiliates



The miracles of science™