the standard in safety

Safety Concerns with New PV Polymeric Materials

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- Joined UL in 1995
- Technical rep on UL STPs for Rigid and Flex PWB Standards
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  - Electrical and Electronic Insulating Materials
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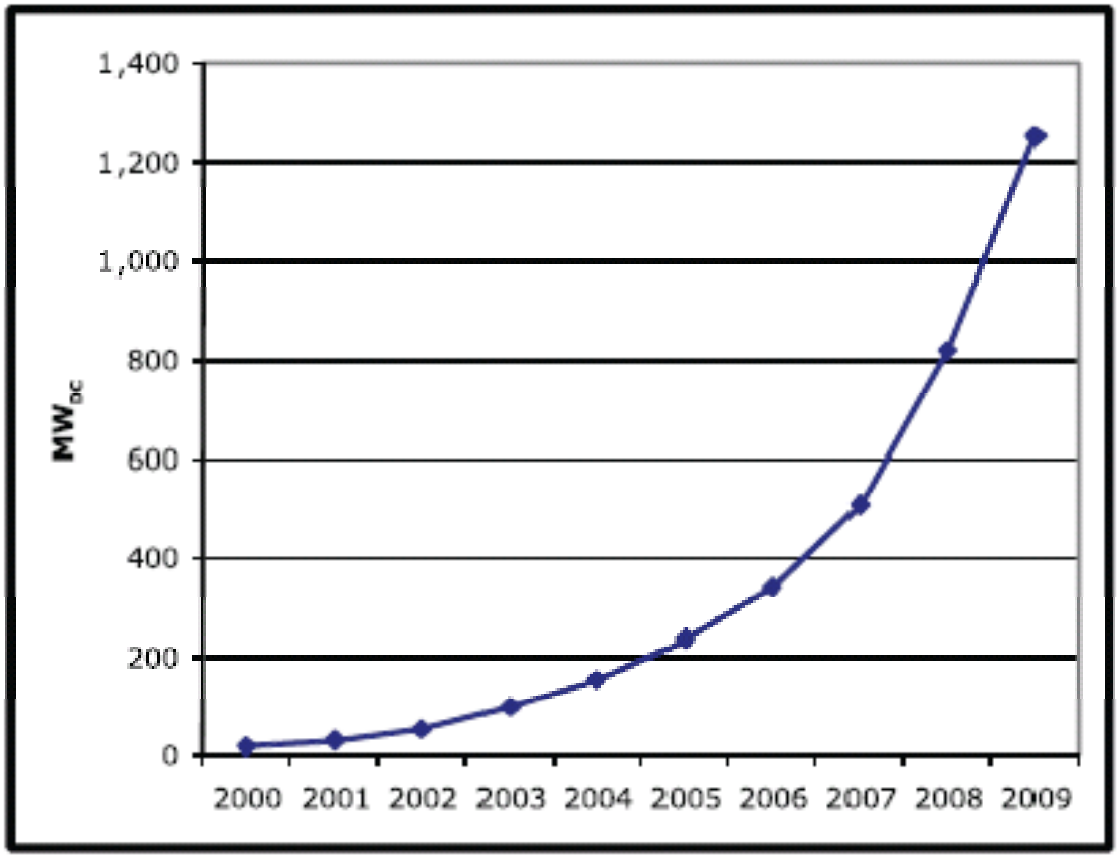
Getting New PV Materials to Market

What this session will cover –

- Changing PV Market
- Safety Risks
- Performance vs Safety Evaluations
- PV Material Standards Work
- PV Materials Pre-selection Process

PV Growth in US

Cumulative US Grid-tied PV Installations 2000 - 2009



Data Source: Interstate Renewable Energy Council Review 2009

PV Module Landscape is Changing

- PV modules produced between 1990 and 2005
  - Share similar constructions, materials, and manufacturing process

- Traditional PV module recipe
  - Developed with many years of research and testing
  - Good track record

Past and Future PV Performance

- Past performance can’t predict the future
  - New PV module configurations and applications
  - New manufacturers with little PV module experience
  - New manufacturing processes
  - New construction techniques

New Construction Techniques for PV

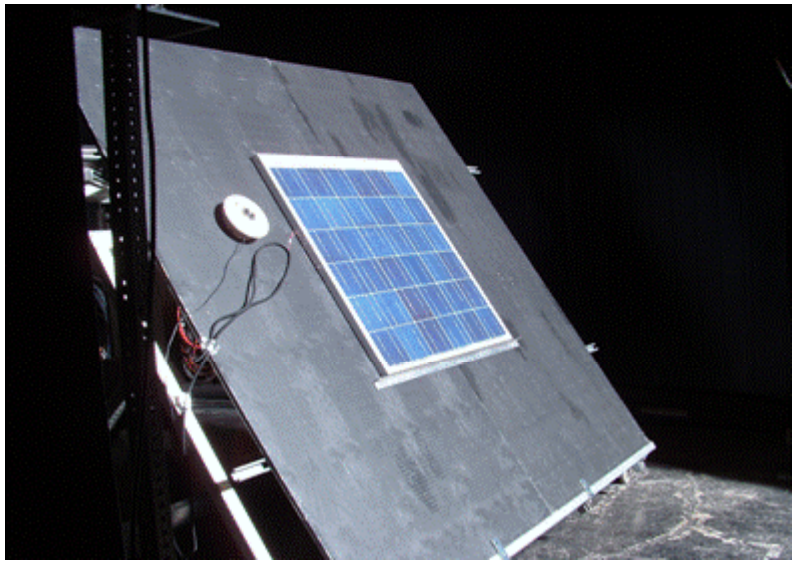
- New PV materials
  - Thermoplastics, encapsulants and adhesives with low softening / melt temps
- Conductive adhesives to replace solder
- Polymeric mounting systems

Thermoplastic Material Concerns

- Transition away from crosslinked EVA
- More thermoplastic encapsulants and mounting materials in the PV construction
- Thermoplastics flow or creep over time when exposed to high operating temperatures
- Some new materials have melt temperatures less than 100C

PV Module Temperature Testing

- Worst case module temperatures are not addressed and can be well above 90C due to
  - High ambients
  - High irradiance
  - Shading conditions



- Temperature tests are normalized to 40C
- Chamber cycling is done at 90C max

PV Polymeric Material Creep or Flow

- Any movement can create problems!
- Risk of shock, fire or mechanical hazards
  - Electrical connections
    - Short or open circuits
    - Displacement of electrical conductors or components
    - Loss of contact pressure
  - Mounting
    - Delamination
    - Loss of mechanical integrity
    - Falling modules or falling glass

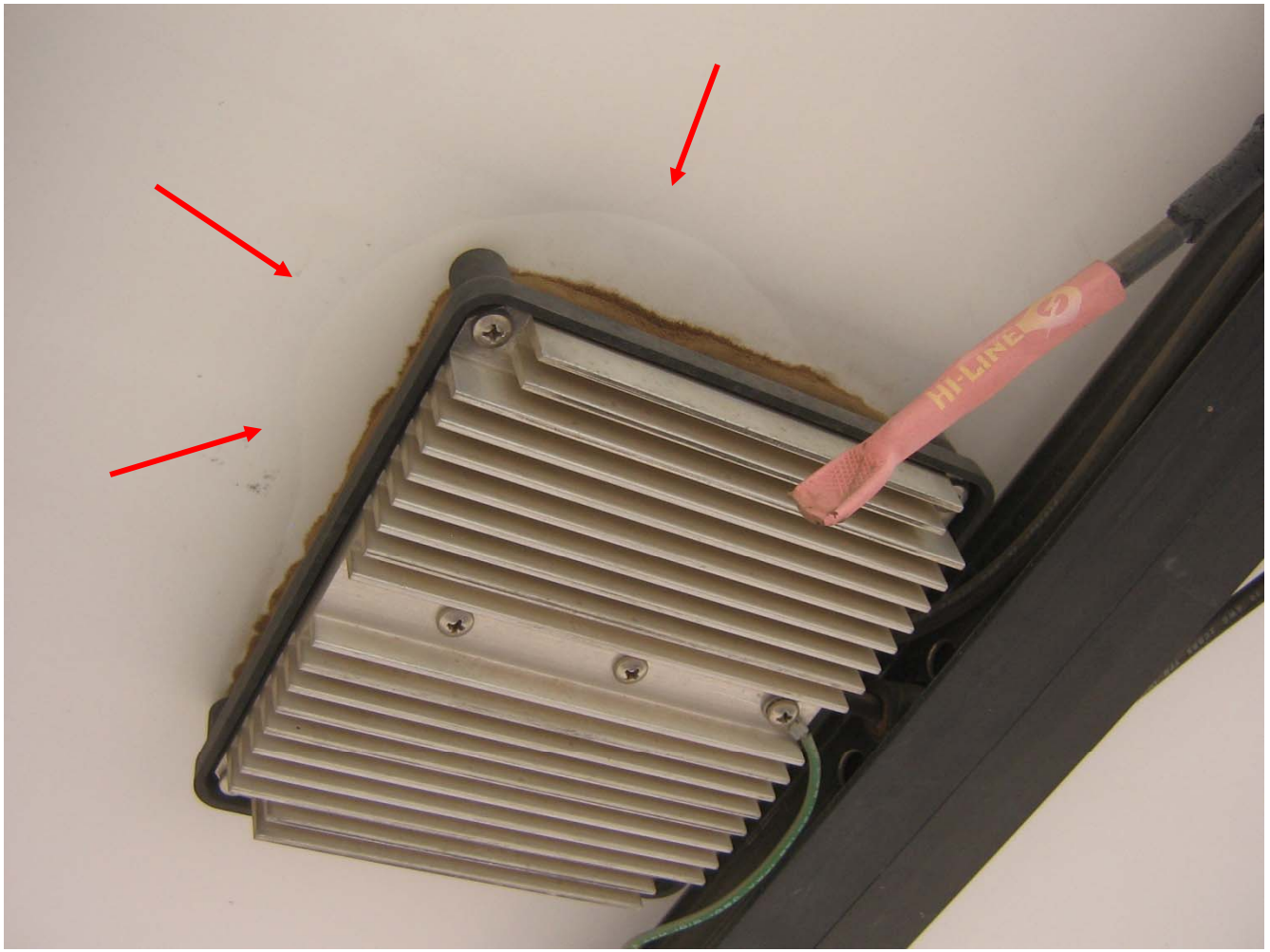
PV Evaluation Challenge!

- Existing evaluation programs are not sufficient
  - Do not address all safety concerns as demonstrated by increased product testing failures
  - New generation of PV modules
  - New components
  - New materials

Why Safety Testing?

– 8 years operation in Arizona
– Passed original qualification tests

Backsheet Delamination




I just need a little more cable …..

Delamination or creep can can cause these ribbons to open or short circuit

“Hazard-Based” Engineering Approach

- Analyze the installation
  - Location and intended use
  - Attachment systems, wiring systems, hazards
- Analyze the product
  - Materials, construction, hazards

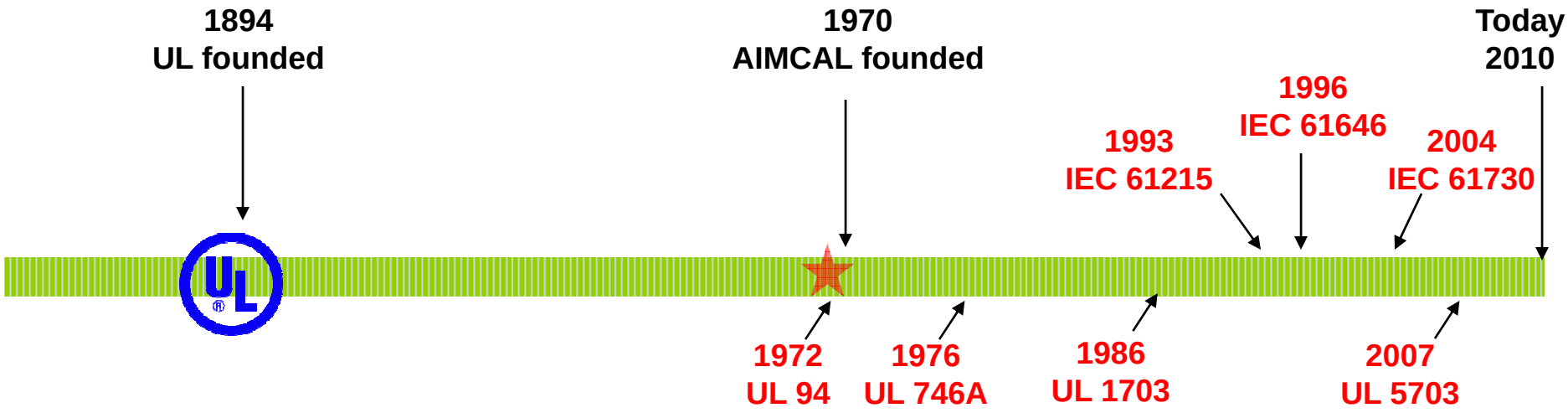
“Hazard-Based” Engineering Approach

- Utilize existing standards & knowledge
  - Standards may exist for similar products / situations
  - Code requirements may exist

- Test to provide confidence
  - Use UL and/or IEC for PV modules
  - Use other standards to address incidental hazards

Who is UL?

- **Underwriters Laboratories Inc (UL) is an independent, not-for-profit safety testing and certification organization**
- **Founded in 1894, UL has earned a reputation as a global leader in product safety standards development, testing and certification**



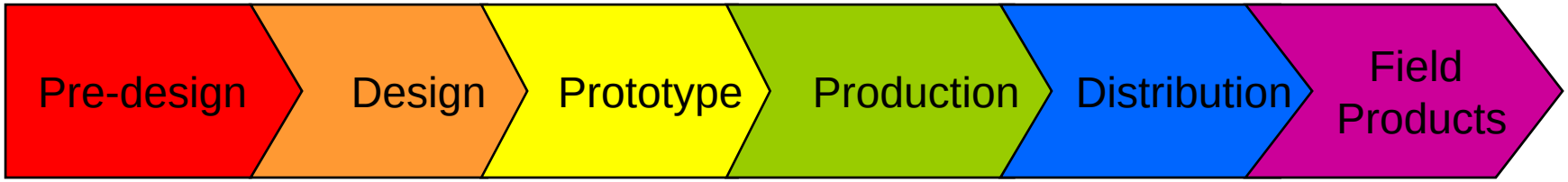
Certification and Product Development Cycle

Performance Certification

IEC 61215 or 61646

One time evaluation, no Follow Up test

If no Follow Up testing: Modules, components and materials may vary and invalidate performance certification



Safety Certification

IEC 61730 or UL 1703

Consulting

Prelim Investigation

Certification

Manufacture Follow-up Inspection and Testing

Product failure Field Reports

IEC 61730 PV Module Safety

- Scope and Objective
  - Describes the fundamental construction requirements for photovoltaic (PV) modules
  - **To provide safe electrical and mechanical operation during their expected lifetime**
  - Specific topics assess the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses

UL 1703 Safety Standard for PV Modules

- Evaluate electrical shock hazards
  - Product and application
- Evaluate fire resistance & propagation hazards
  - Product and application
- Verify evaluation through testing
- Provide subsequent “Follow-Up” inspection of manufacturing locations

UL 5703 PV Backsheet Materials

- Outline of Investigation

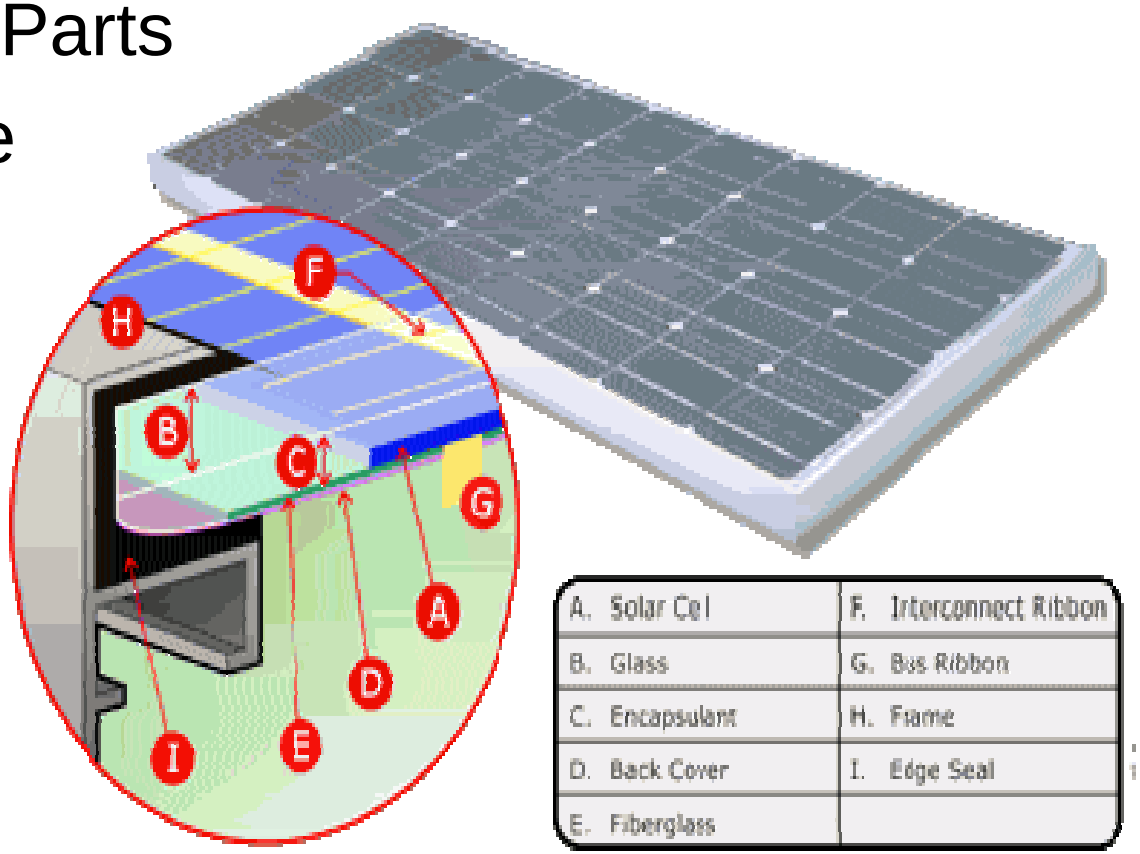
- Scope – Evaluation of PV materials including backsheet and encapsulant materials
  - Long term temperature rating evaluations
  - UL746A Short term property characterization

- Frontsheet and conductive adhesive requirements to be added

- Provide subsequent “Follow-Up” inspection of manufacturing locations

Applications

- Enclosure
- Support of Live Parts
- Outer Enclosure
- Barrier / Liner
- Junction Boxes
- Thermal Index



A. Solar Cel	F. Interconnect Ribbon
B. Glass	G. Bus Ribbon
C. Encapsulant	H. Frame
D. Back Cover	I. Edge Seal
E. Fiberglass	

Material Property Requirements

- Short Term (depends on operational category)
  - Encloses live parts
  - Direct support of live parts
  - Outer surface for the module
  - Internal Barrier (in lieu of spacing requirements)

- UV / Water Exposure

- Long Term (all polymeric materials must have):
  - Rating of Tmax + 20ºC, where Tmax is the max measured temperature during the Temperature test
  - If material is backsheet / frontsheet, shall be min 90ºC

Short Term Material Tests

- Comparative Tracking Index (CTI)
  - determine spacing requirements with addition of wet contaminant
- Dielectric Strength (DS)
  - establish insulation resistance baseline
- High Current Arc Ignition (HAI)
  - simulate loose connections and broken leads
- Hot Wire Ignition (HWI)
  - determine ignition properties when adjacent to or supporting an insulated or uninsulated wire
- Volume Resistivity (VR)
  - determine if material is an insulator or a semi-conductive material

Relative Thermal Index (RTI)

- A temperature assigned to the dielectric material
  - Does not unacceptably degrade the material
  - Electrical and Mechanical properties

- Determined by a benchmark comparison of temperature, time, and critical property degradation after long-term thermal aging

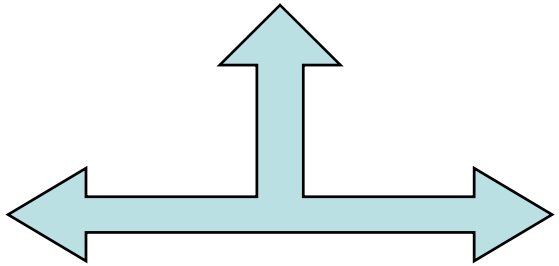
Harmonization of IEC and UL Standards

- Goal to minimize national differences
  - IEC 61730 Amendment
- Revisions include
  - Standardize PV material characterization tests
  - Module level tests to address creep, flow, displacement and delamination failures
  - New outlines for PV Connectors, Cables and J-Boxes

International Information Transfer

IEC PV Plastics
Project Team

UL 61730



IEC 61730

IEC PV Material Characterization Project Team
(TC82, WG2)

- Scope
  - Develop PV material property characterization requirements
- Hazard Based Analysis
  - Used to determine material characterization tests
- 88 International members
  - Module, adhesive, backsheet, and encapsulant mfrs, industry experts, certification bodies, and national labs

IEC PV Material Task Groups

- Adhesives and Conductive Adhesives
- Backsheets and Frontsheets
- Edge Sealants and Potting Materials
- Encapsulants
- Partial Discharge
- Weathering/accelerated aging

IEC PV Material Meeting Schedule

- Material Project Team
  - Meet twice a year with TC82 WG2
  - Next meeting May 2011 Shanghai, China

- Task groups
  - Meet in between WG2 meetings via teleconference with Internet meeting (web-meeting) and/or face to face meetings

IEC PV Material Project Team

- Short and Long Term Goals
  - Work related to IEC safety, design, and performance standards
    - IEC 61730, IEC 61215, IEC 61646
  - Characterization of safety and performance
  - Review and prioritize test lists based on safety and performance
  - Create retest variation guidelines
  - Compliance criteria based on design and application
  - Preselection guidelines for modules

Hazard	Failure Mechanism	Test	Test Method
Electric Shock	Electric strength – dielectric breakdown due to degradation of insulating material	Dielectric Strength	IEC 60243, IEC 60216-5 (thermal aging)
	Voltage tracking – voltage causing a permanent electrically conductive carbon path after application of wet contaminants.	CTI	IEC 60112
	Material electrically conductive	Volume Resistivity	IEC 60167
	Insulation thickness consistency	Partial discharge	IEC 61730-2
	Mechanical protection from tearing	Tensile Strength, Tear Resistance, Cut Test	ISO 527-3, ASTM D1004, IEC 61730-2
	Mechanical protection from punctures due to installation tools	Puncture Properties	ASTM D7192
	Mechanical support of junction box due to movement or stretching of backsheet	Tensile Creep	ISO 899
	Superstrate / Glass movement/creep	Creep/flow test,	D6382
	Substrate / Encapsulant movement from J-box and cable weight	Dynamic Mechanical Analysis (DMA)	
	Interfacial Delamination/adhesion	Bond strength,	??
	Common failures include crazing (micro scale) that grow to cracking and mechanical failures. SEM or TEM optical microscope to view	Peel strength, Intra-layer adhesion	SAE Automotive or IEC 60950-1 (2.10.11)
	Water ingress from delamination	Water Absorption	ISO 62
Flammability	Additional fuel for the fire	Flammability test, Radiant Heat Ignitability (Cone Calorimeter test)	IEC 60695-11-10, ISO 5657
	Insulated or uninsulated wire attaining red heat during a fault causing possible ignition	HWI or Glow Wire	IEC 60695-2-20
	Loose connections and broken leads in the vicinity of the polymer material causing arcing	HAI	IEC 60695-1-1
Mechanical	Mechanical failure due to degradation of insulating material	Tensile Strength and Tensile Elongation	ISO 527-3, IEC 60216-5 (thermal aging)
	Thermal stress due to material expansion	Thermal Expansion (CTE)	ISO 11359-2
	Adhesion to glass and backsheet	Bond strength, Peel strength	?? SAE Automotive or IEC 60950-1 (2.10.11)
	Inter-layer adhesion of backsheet	Bond strength, Intra-layer adhesion	?? SAE Automotive or IEC 60950-1 (2.10.11)
	Surface treatment, chemical, corona treatment	Surface finish rating scale for machined metals?	??

Potential Solutions to Assembly Challenges

- Pre-selection of materials
- Select alternate materials with higher temperature ratings for assembly

Pre-selection

- The process of assessing and choosing materials for electrical products.

Advantages of Pre-selection

- **Aides in material selection during the design stage**
- **Compare and evaluate performance levels**
- **Eliminate testing each material in specific part configurations**
- **Faster qualification of alternate materials**
- **Pre-selection successfully used as a material performance specification in product standards for decades**
- **Faster time to market**

Summary

- ✓ **Enables users to locate suitable materials for higher temp applications**
- ✓ **Pre-selection programs eliminate the need to test each material in each specific part configuration**
- ✓ **Faster qualification of alternate materials**
- ✓ **Confidence that the materials continue to meet requirements (type testing and on-going verification)**
- ✓ **Faster time to market**

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Thank You
for your attention
and future participation!

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