

Durability of Optical Materials



Capture
the Power of 3M

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Outline

- 3M Background
 - *Optical Products*
 - *Weathering Expertise*
- Considerations in setting up weathering testing
 - *Typical Test Regimens*
 - *Optical Testing of Samples*
 - *Definition of Failure*
- Example Outdoor Results



3M Optical Products for the Solar Market



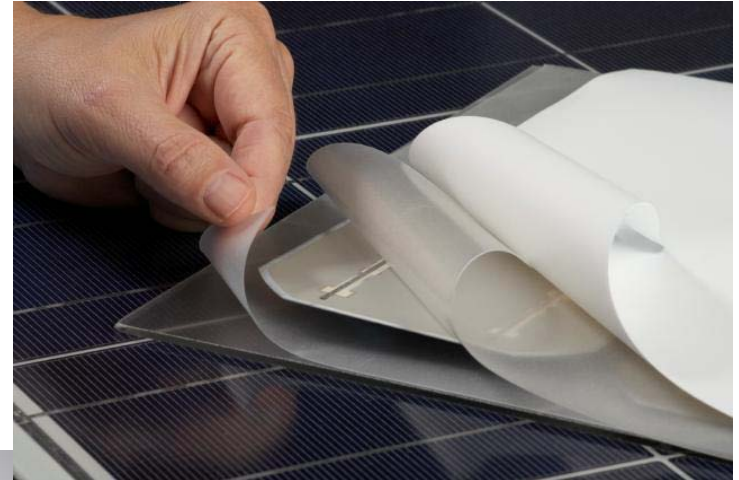
Mirror
Films



Silicone on Glass
Fresnel Lens Panels



Acrylic
Fresnel Lens Panels



PV Backsheets



Barrier Films

3M Weathering Resource Center

Description:

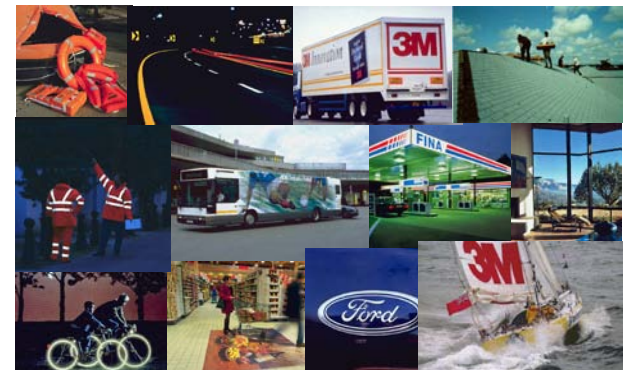
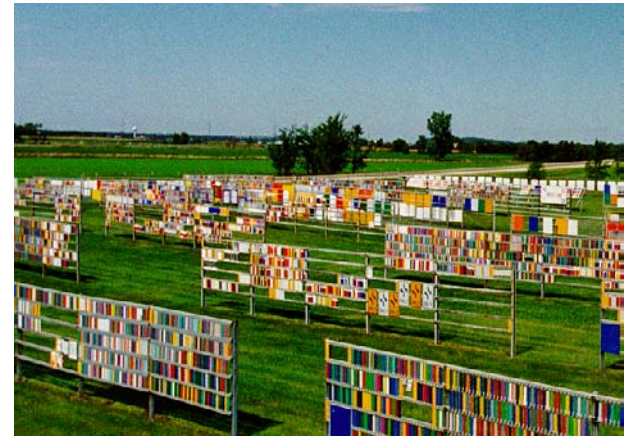
- *The Weathering Resource Center is a 3M facility that provides testing and research services for the study of material failures resulting from exposure to light, heat, and moisture. Controlled outdoor weathering is conducted in a number of global locations. Accelerated weathering devices are operated in the WRC laboratory to provide similar environmental stresses on materials and constructions, but in a shorter time frame.*

Value Proposition:

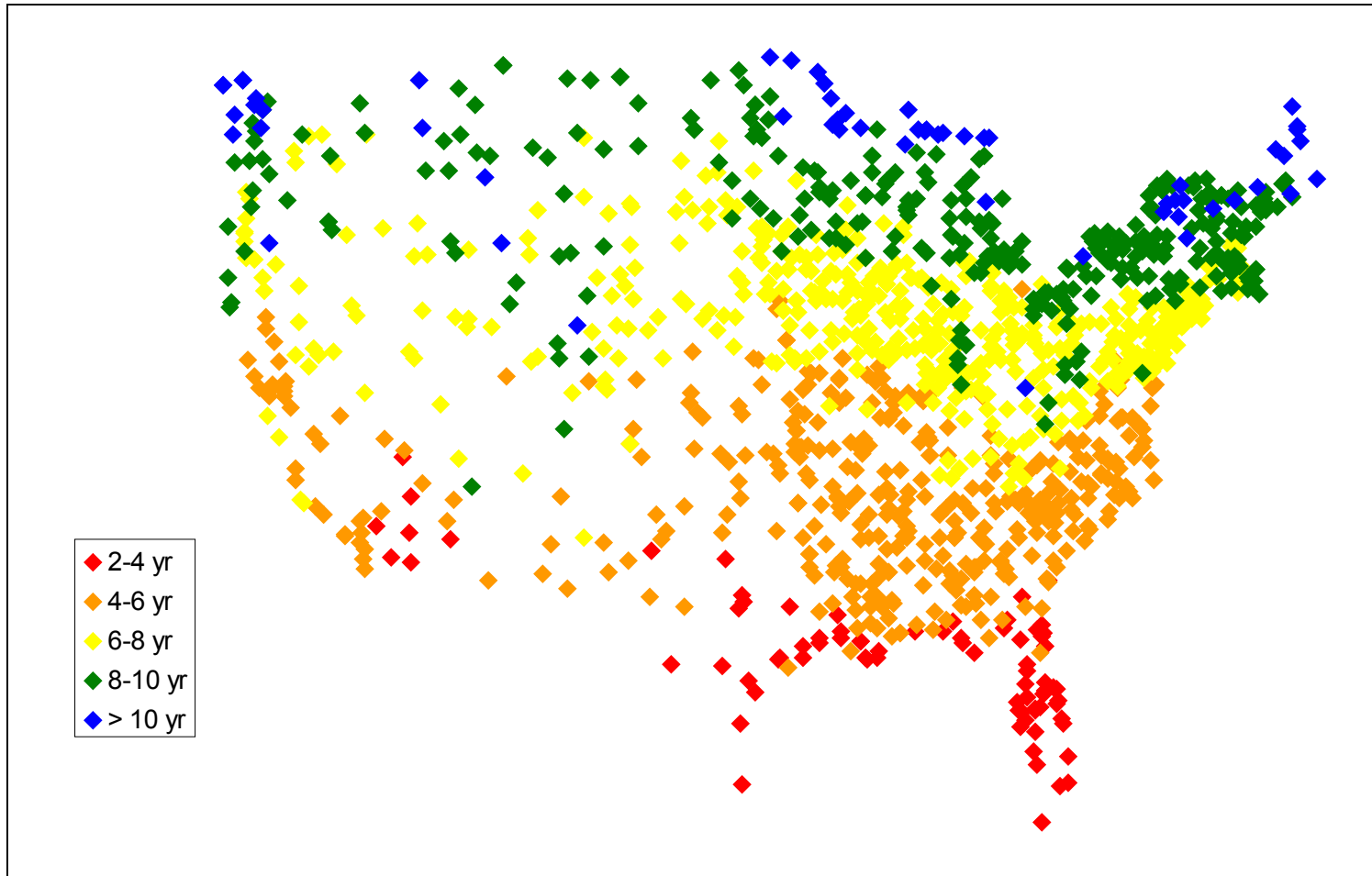
- *The WRC's unique ability to support research of the degradation effects and lifetimes of many product types across many 3M divisions leads to increased product durability and improved product reliability.*

Technical Benefits:

- *The WRC has developed a number of proprietary laboratory tests that exhibit very good correlation with natural weathering results. Faster tests are achieved through the use of patented light sources that yield higher levels of realistic solar radiation.*



Example Product Lifetime Map (Product Unknown)



Estimating material or product lifetimes. *By means of a series of proprietary accelerated weathering tests that determine the relative effects of light, heat, and moisture on degradation, mathematical models may be derived and used with climate data from specific locations in order to estimate lifetimes.*



Typical Test Regimen

New Products/New Material Sets

Accelerated Indoor Testing

- *Battery of tests for light, heat, & humidity responses*
- *Test to Failure, typically more than 10,000 hours (~15 months)*
- *IEC-62108*

Outdoor Testing

- *Locations: Arizona, Florida, and Minnesota*
- *Durations: 1 year, 5 year, 10 year periods & retest until failure*

Product Modifications

Accelerated Indoor Testing

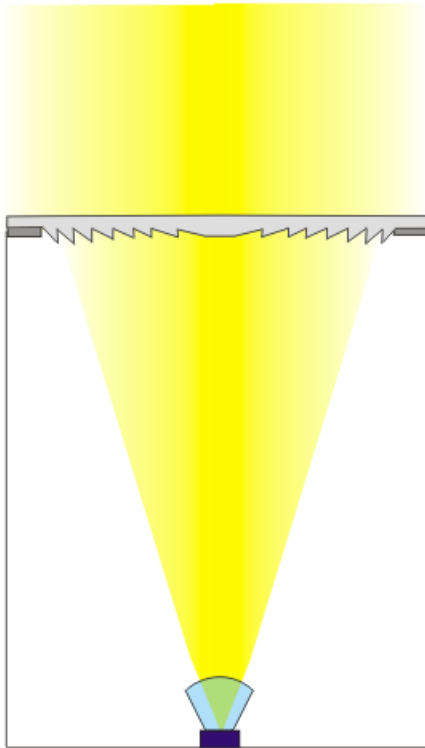
- *Most aggressive accelerated test, with standard product as a control*
- *IEC-62108*

Outdoor testing

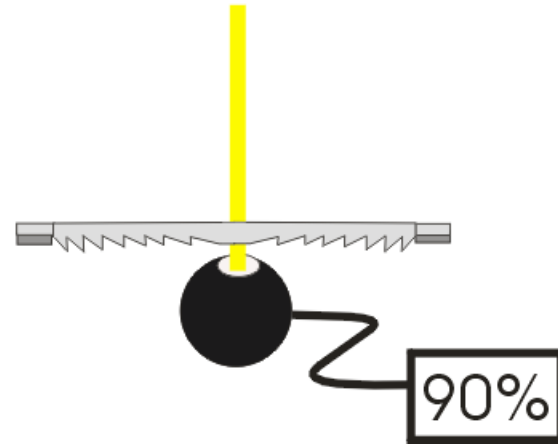
- *Same as for new products*



Testing Lens Transmission



Typical Application

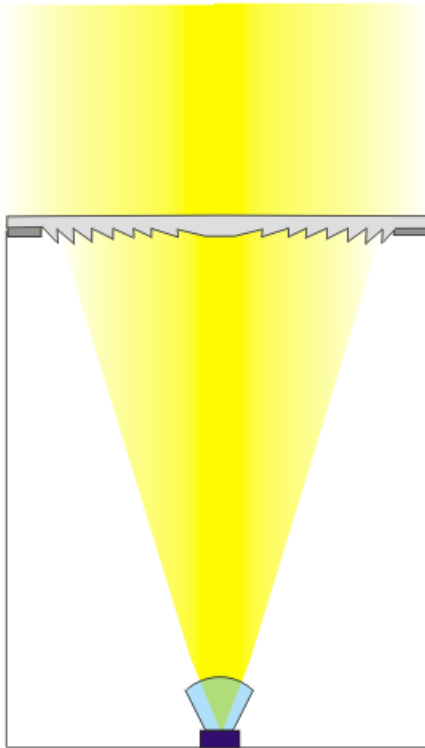


Diffuse Transmission

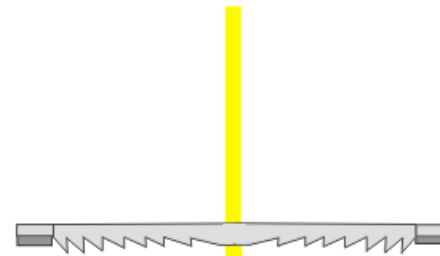
Nearly all light that gets through the lens is included in measurement



Testing Lens Transmission



Typical Application



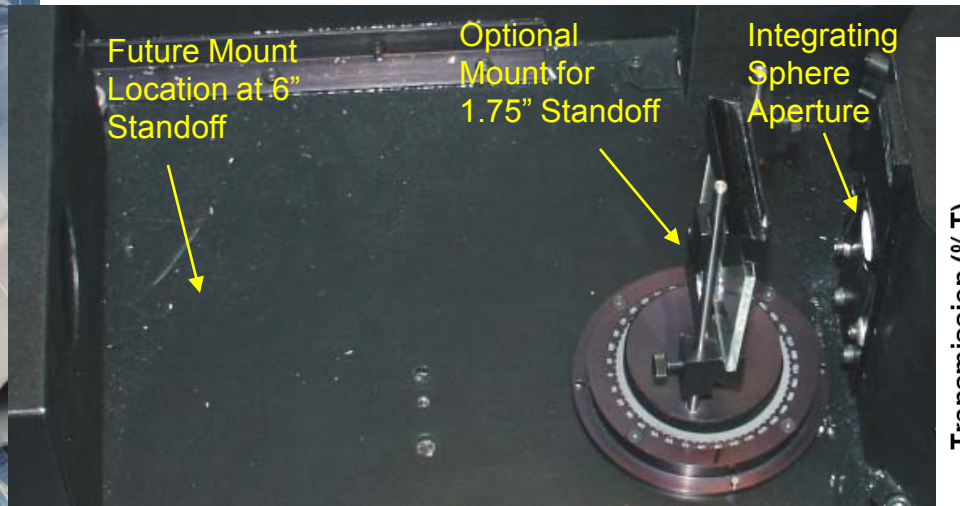
Specular
Transmission

*Only Light that would get to
the PV cell is included in the
measurement*

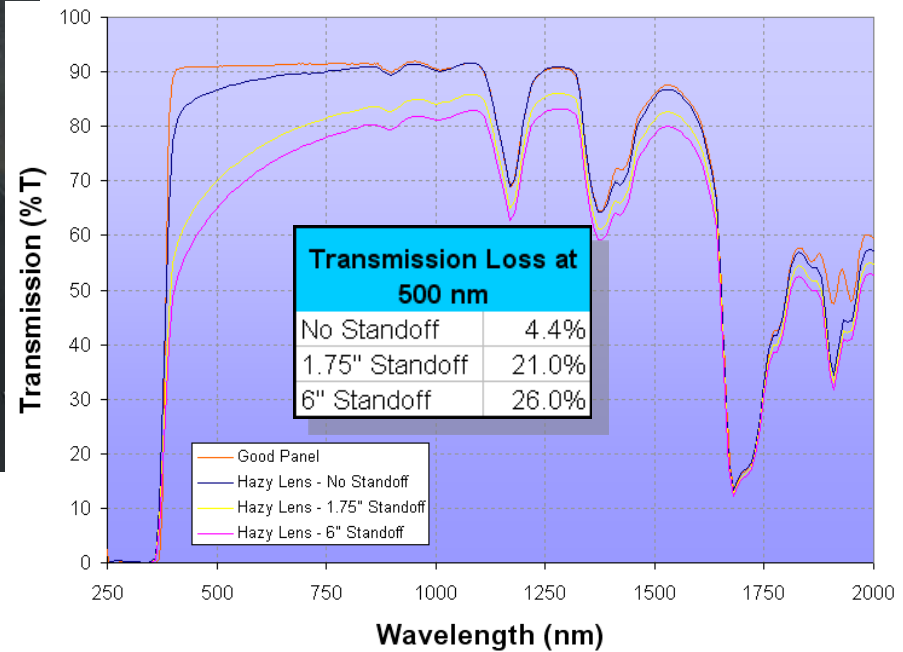
- *Haze rejection*
- *Stray Light Rejection*



Testing Lens Transmission



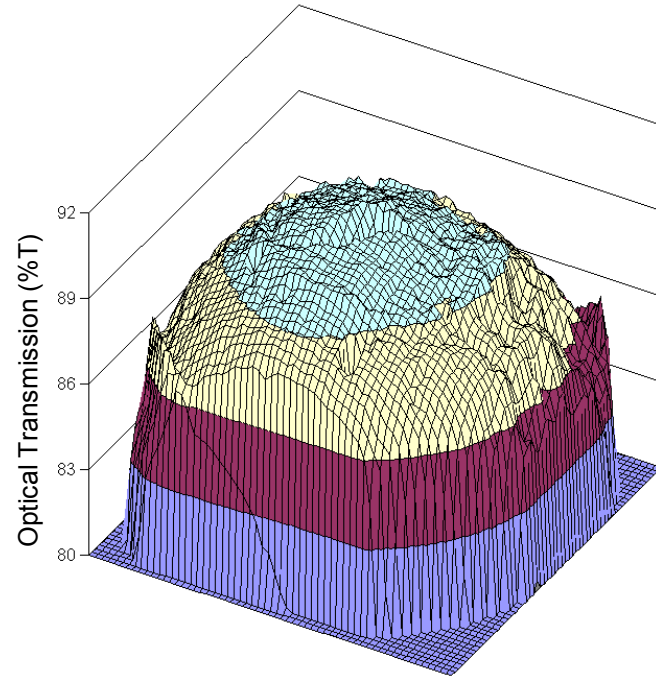
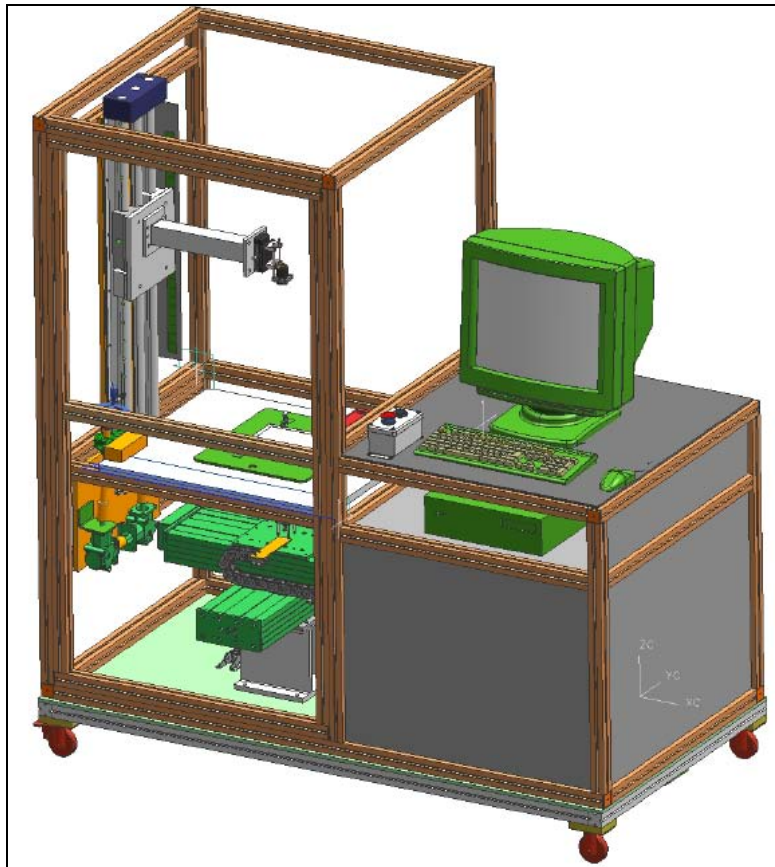
Inside of a Perkin Elmer Lambda 900 spectrometer, showing three locations where the sample was placed to get the results shown to the right.



Lens Transmission as a function of detector standoff for a very hazy sample



Testing Lens Transmission



Surface plot of data measured on Lens Efficiency Tester pictured at left. This tester, which measures efficiency at discrete points across the lens, is helpful in highlighting non-uniformities in lens transmission.



Testing Methodology – Sample Cleaning

- Samples will be periodically washed in the application, should washing also be a part of testing?
- Some washing will occur in outdoor samples, and accelerated tests often have a wash cycle.

Factors to consider in washing

- *Use of detergent?*
- *Spray Pressure*
- *Cleaning materials and scrub pressure during use*
- *Polishing compounds*
- *Wash Period*
- *Use of solvents*
- *Purity of wash materials/sources of residue*



Outdoor Testing Considerations

Improper Control of Water

- Can foster growth of Algae
- Excessive heat and water can lead to crazing
- Condensing/Evaporation cycles can leave residue

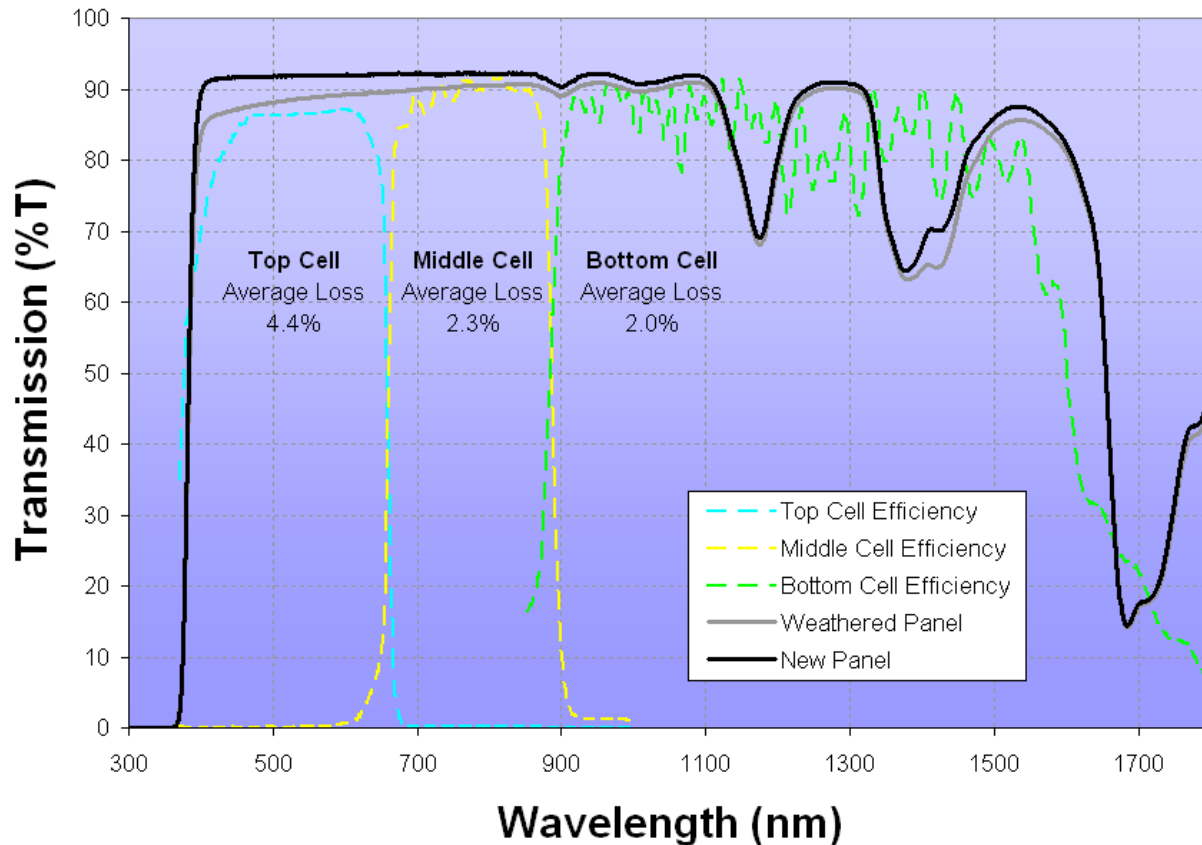
Lens Mounting

- Should be no pockets for dirt accumulation
- Should be sealed to prevent water intrusion
- Should be vented to allow escape of water
- Requires custom mounts

Outdoor testing considerations are similar to the considerations faced by CPV manufacturers and installed systems are probably the best source of outdoor weathered samples.



Definition of Failure – Optical Considerations



Transmission loss in a weathered panel leads to uneven losses in the three junctions of a triple junction cell. Should failure be written in terms of average transmission loss over the complete spectrum or average transmission loss across the top junction?



Definition of Failure – Mechanical Concerns

- Visual Inspection is still needed for anomalies that may lead to failure

- *Crazing*
- *Bubbles*
- *Warping*
- *Delamination*

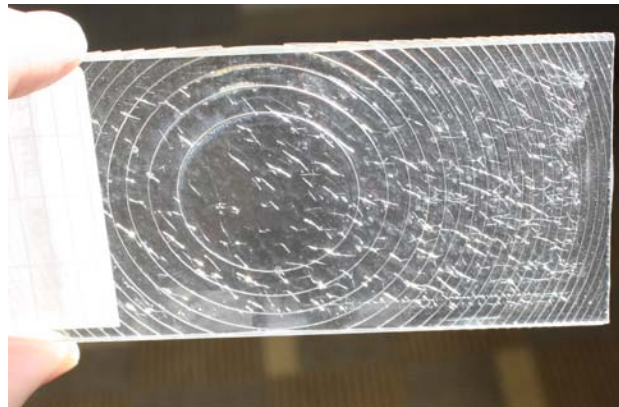
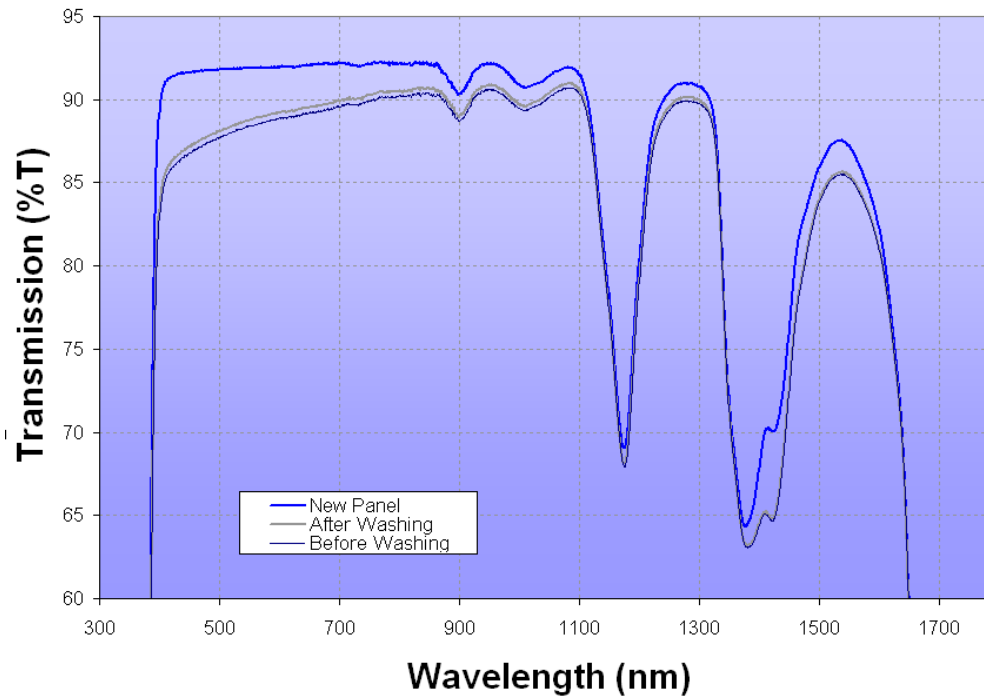


Image of a crazed injection molded lens (not produced by 3M) after time in an accelerated test. Not all PMMA lenses perform the same.

- Acceptable levels of anomalies like these still need to be defined, so it is unclear how they would be included in a definition of failure

Analysis of installed lens panels



Measured transmission of a linear Fresnel lens from the system pictured after 13 years in service in Minnesota. This system survived winds over 30 meters/second and temperatures from -30F to 90F with little or no cleaning of the optical surfaces.

