Relating Artificial Weathering Testing to Service Life Estimation of Structural Glazing Systems

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ASTM C24 Third Symposium
on
Durability of Building and Construction Sealants and Adhesives

Weathering Resource Center (WRC)

3M Global Corporate center for weathering research and testing
serve 30 divisions; collaborate w/200+ researchers

Mission

Develop and validate weathering test protocols to reliably estimate in-use service life of materials and systems

Structural Glazing

Introducing <u>New</u> Technologies, Materials and Systems

- •Faster cure
- •Easier to Use/Maintain
- •More Consistent Properties
- •Less Expensive

Fulfill Long Service Life Requirements& Expectations (>20 years)

Relating Artificial Weathering Testing to Service Life Estimation of Structural Glazing Systems

- Overview of the current laboratory weathering test procedures used to specify structural glazing bonding systems

- Compare the stresses provided by these test protocols to those expected in field applications.

- A comparative example to illustrate the requirements for artificial accelerated weathering testing of materials intended for high durability applications.

- Recommendations

Designation: C 1184 – 05

Standard Specification for Structural Silicone Sealants[1]

1. Scope

1.1 This specification describes the properties of cold liquid applied, single-component or multicomponent, chemically curing elastomeric structural silicone sealants herein referred to as the sealant. These sealants are intended to structurally adhere components of structural sealant glazing systems.

Designation: C 1184 – 05

Standard Specification for Structural Silicone Sealants[1]

TABLE 1 Requirements for Physical, Mechanical and Performance Qualities of the Sealant

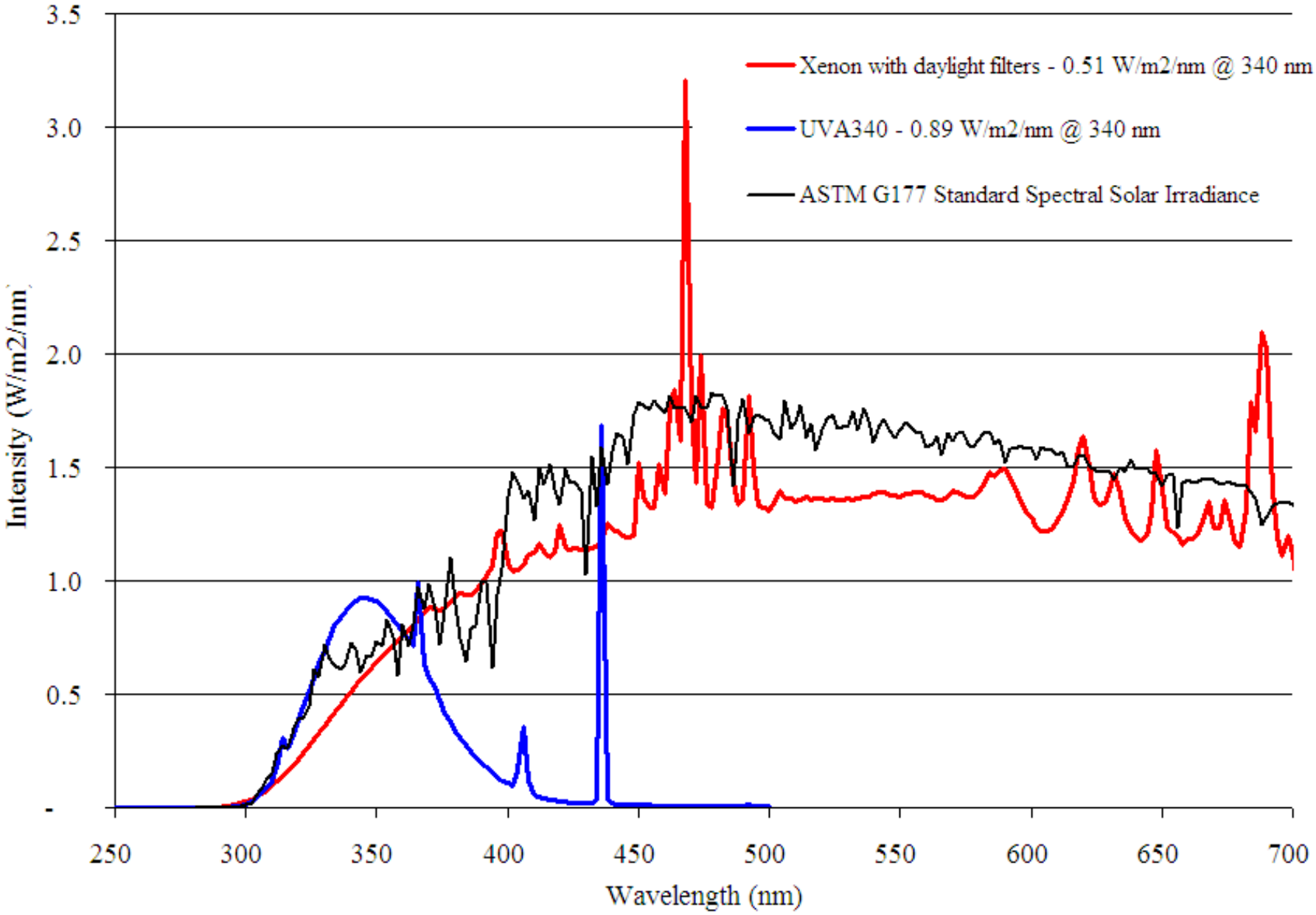
Property	Requirement	Test Method
Rheologic, max		C 639
Vertical	4.8 mm (3⁄16 in.)	
Horizontal	no deformation	
Extrudability, max	10 s	C 603
Hardness, Shore A	20-60	C 661
Heat aging		
Weight loss, max	10 %	
Cracking	none	
Chalking	none	
Tack-free time, max	no transfer in 3 h	C 679
Tensile value, min		C 1135
Standard conditions:	345 kPa (50 psi)	
88°C (190°F)	345 kPa (50 psi)	
–29°C (–20°F)	345 kPa (50 psi)	
Water immersion	345 kPa (50 psi)	
5000 h weathering	345 kPa (50 psi)	8.6.2.5
Shelf life, min	6 months	9.1

8.6.2.5 Expose five specimens with the bond surface facing the light source to either of the exposure conditions specified below in apparatus that conforms to the requirements defined in Practice C 1442.

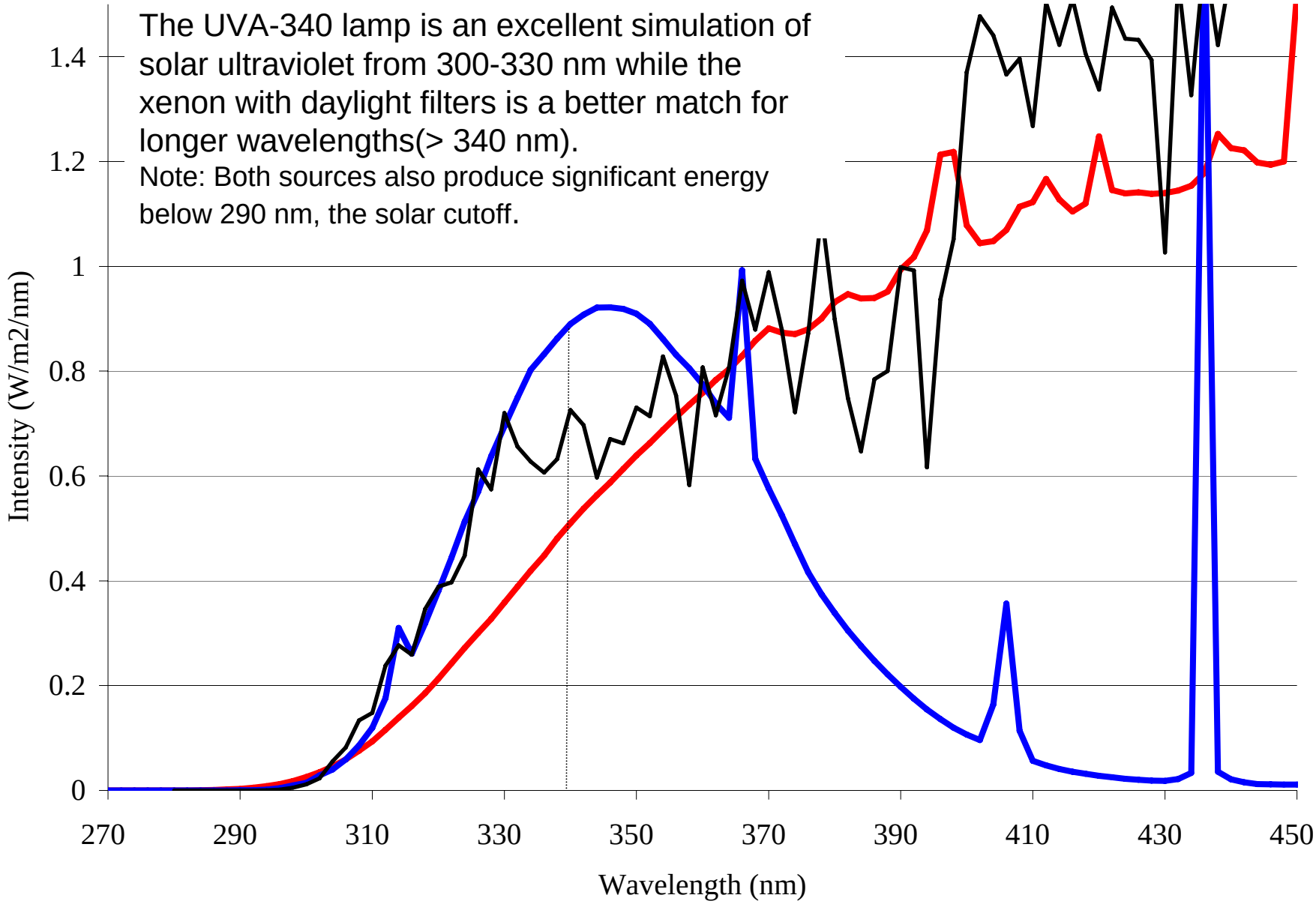
	Exposure Parameters	
Apparatus	Fluorescent UV/Condensation	Xenon Arc
Light source	UVA-340 lamp	Xenon Arc with daylight type filters
Irradiance at 340 nm ($W/m^2/nm$)	0.89	0.35 or 0.51
Uninsulated Black Panel Temperature (BPT)	60°C	70°C
Exposure cycle:		
Light	8 hrs	102 min light only/ 18 min light with wetting
No Light	4 hrs	--
Wetting	wetting by condensation during "no light"; BPT 50°C	wetting by front face water spray (or immersion)
Exposure Duration:		
Minimum Time	5000 hr*	--
Minimum Radiant Exposure	--	9180 $kJ/m^2/nm$ @ 340 nm

* Equivalent radiant exposure =10,680 $kJ/m^2/nm$

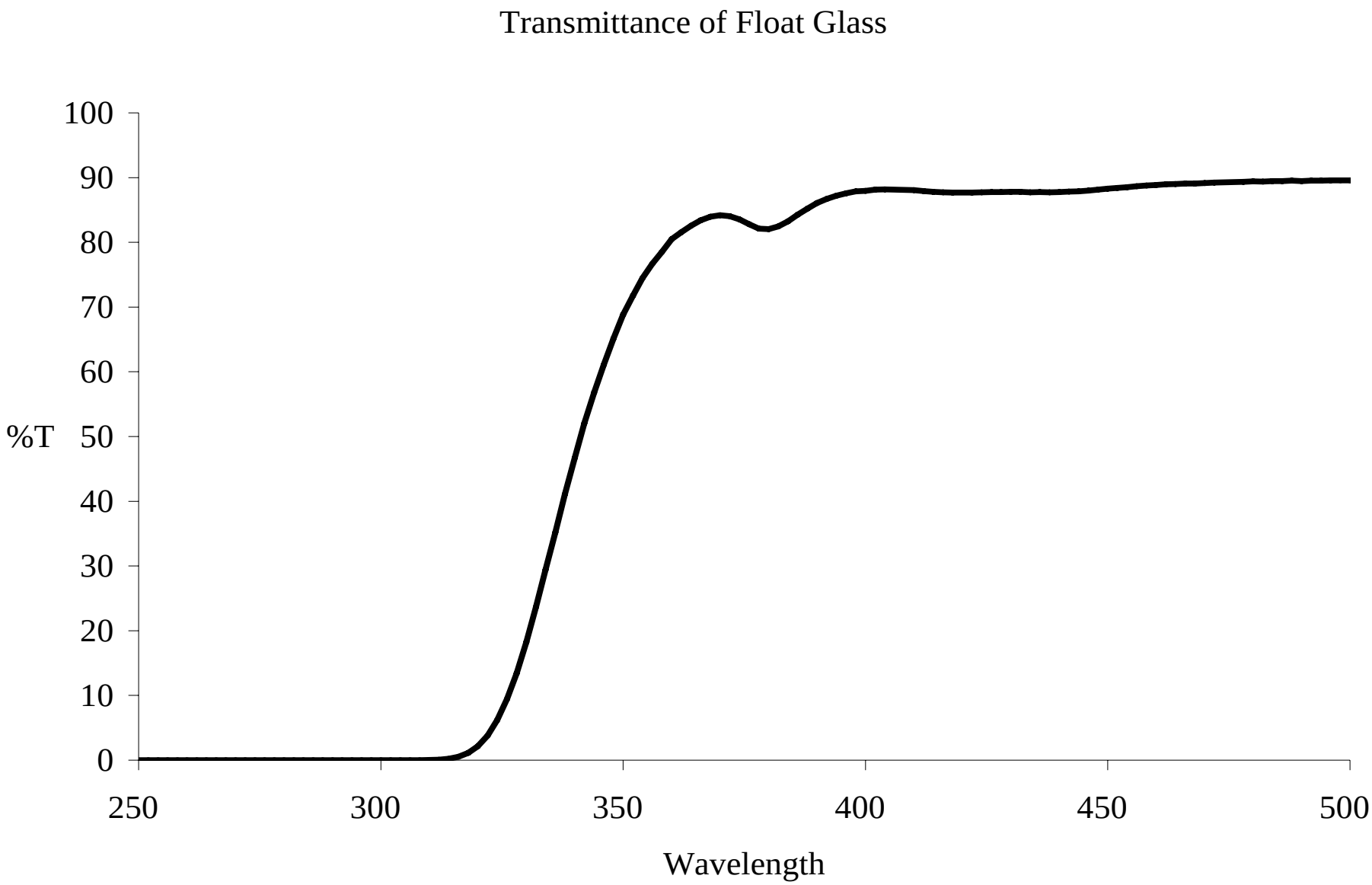
Comparison of Artificial Weathering Light Sources and Standard Daylight



Comparison of Artificial Weathering Light Sources to Standard Daylight in the Ultraviolet and Short Wavelength Visible



7.3 The standard substrate for this specification is clear, uncoated float glass.



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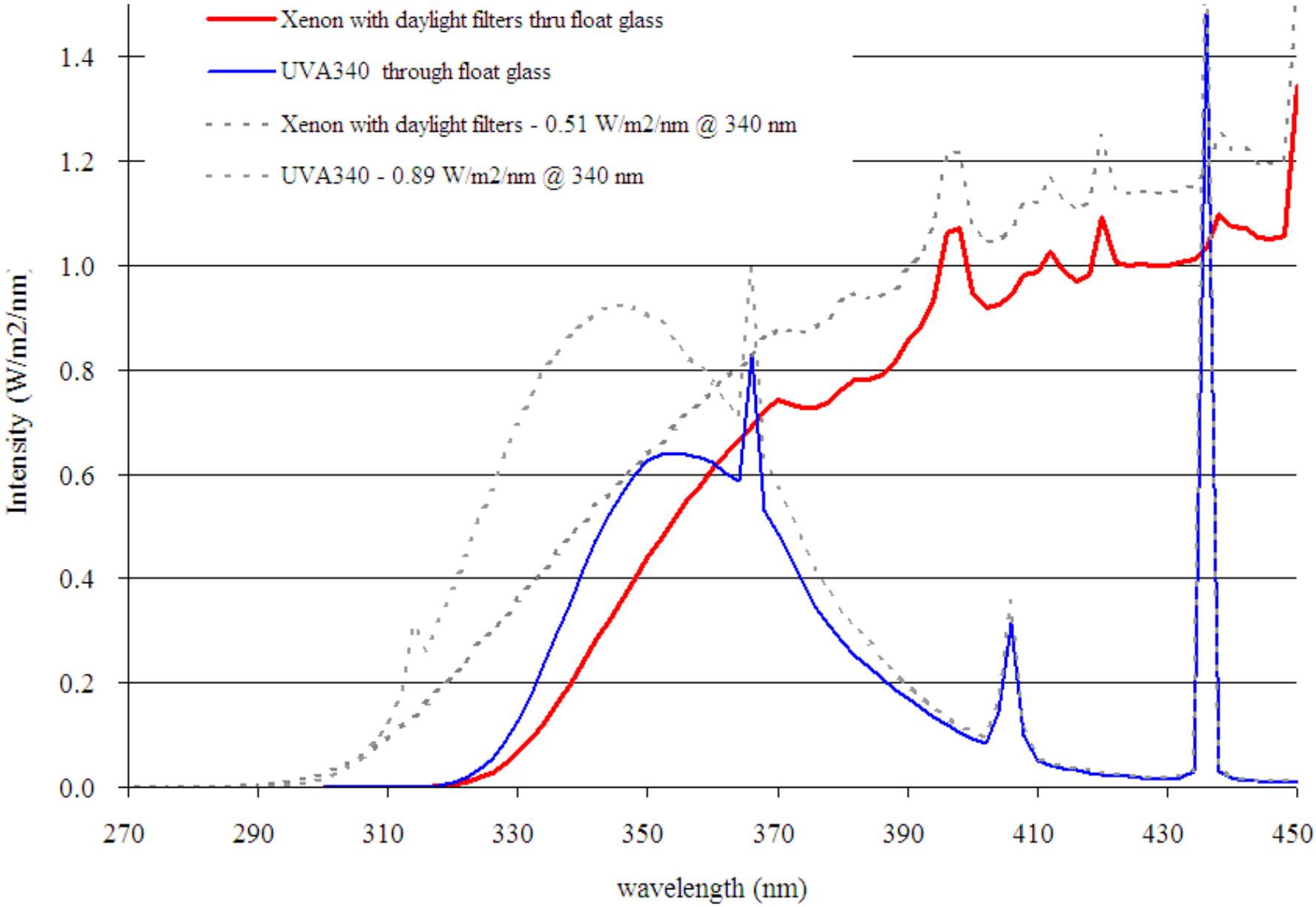
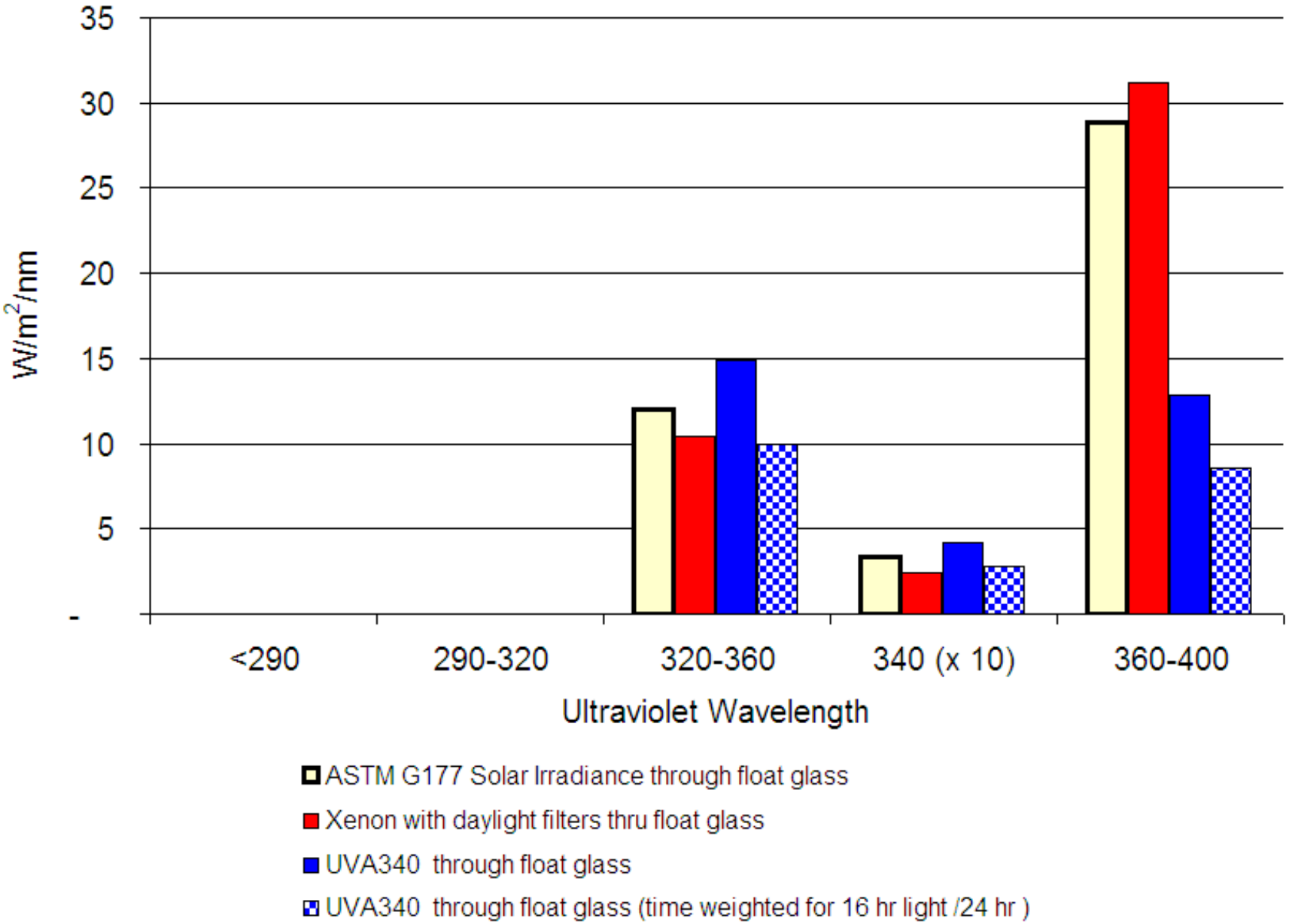


Irradiance at the Bond Surface (structural adhesive-float glass interface)



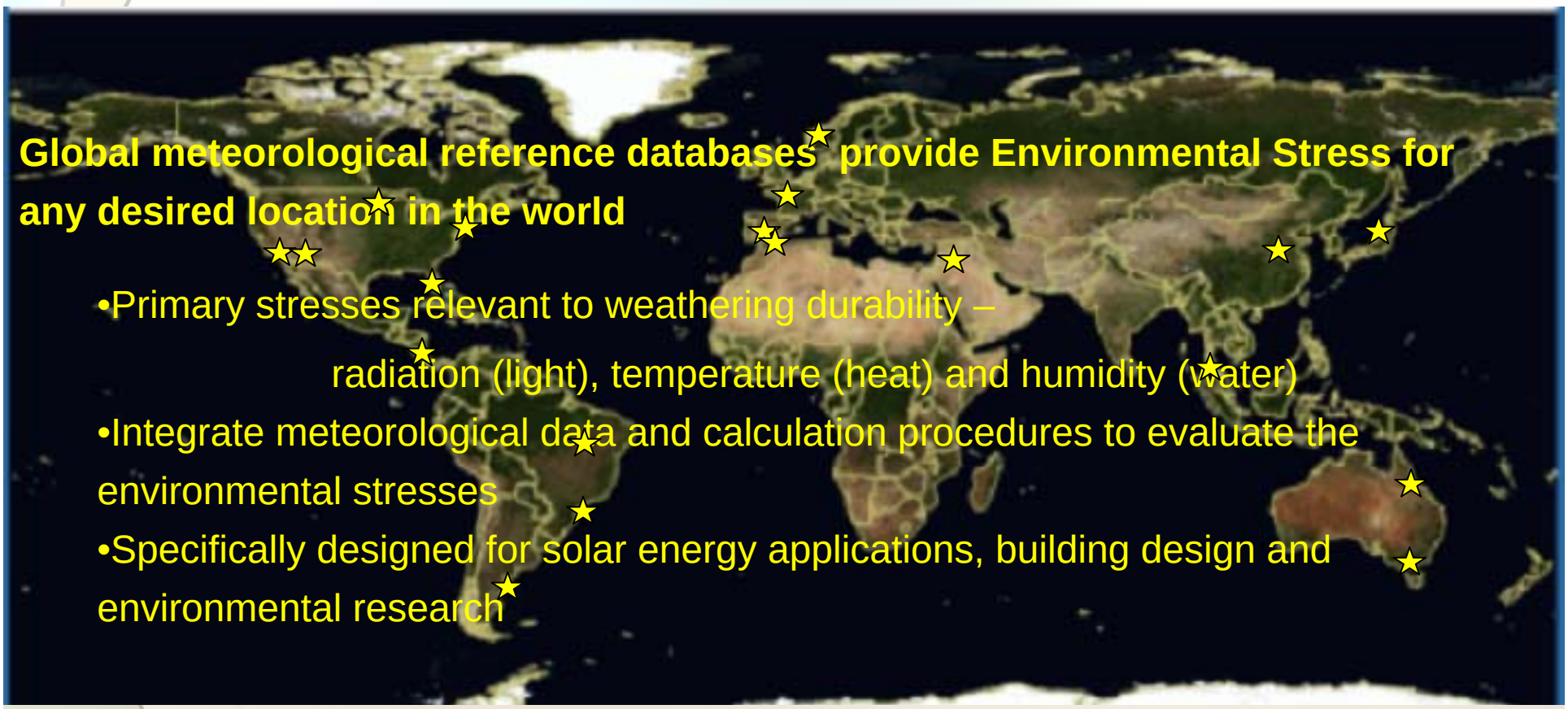
In order for the ‘equivalency’ of the two different exposures allowed in ASTM Specification C1184 (UVA 340 & Xenon Arc w/daylight filters) to be generally valid:

1) Activation spectra for degradation of all structural glazing systems must be be essentially the same

2) Degradation controlled by UV radiation in 320-360 region.

These assumptions may NOT be valid when comparing systems based on dissimilar materials technology.

Relating the stresses provided by artificial weathering protocols to stresses in field applications.



Global meteorological reference databases provide Environmental Stress for any desired location in the world

- Primary stresses relevant to weathering durability – radiation (light), temperature (heat) and humidity (water)
- Integrate meteorological data and calculation procedures to evaluate the environmental stresses
- Specifically designed for solar energy applications, building design and environmental research

Average Annual Total Energy, Ambient Temperatures and Average Relative Humidity for model Equatorial facing Vertical Building Exterior as a function of location

City	Country	Average Annual Total Energy at 340 nm	Ambient Temperature (^oC)				Relative Humidity	Average Annual Total Radiant Dose at 340 nm	Time to a Total Radiant Dose of 9180 $kJ/m^2/nm$ at 340 nm
		$W \cdot hr/m^2/nm$	T_{min}	T_{avg}	T_{max}	ΔT (max-min)	$\%RH_{avg}$	$kJ/m^2/nm$	Years
Singapore		426	15	28	41	26	86	1532	6.0
Paris	France	499	-6	12	37	43	79	1796	5.1
Oslo	Norway	543	-19	8	34	53	74	1956	4.7
Tokyo	Japan	570	-4	17	41	45	66	2053	4.5
Guatemala	Guatemala	648	6	20	36	30	75	2334	3.9
Beijing	China	656	-15	14	43	58	58	2360	3.9
Miami, FL	USA	661	13	26	42	29	74	2380	3.9
New York, NY	USA	661	-13	14	41	55	63	2381	3.9
Barcelona	Spain	662	1	17	40	40	68	2382	3.9
Baghdad	Iraq	732	-3	23	50	54	48	2634	3.5
Minneapolis, MN	USA	735	-30	8	41	71	70	2647	3.5
Madrid	Spain	748	-4	15	40	44	65	2694	3.4
Los Angeles, CA	USA	767	5	20	41	36	70	2761	3.3
Phoenix, AZ	USA	869	-3	25	49	52	38	3129	2.9
Sao Paulo	Brazil	553	9	20	37	28	78	1991	4.6
Brasilia	Brazil	662	10	23	39	29	69	2383	3.9
Melbourne	Australia	708	-1	16	37	38	69	2549	3.6
Buenos Aires	Argentina	727	1	19	38	37	73	2618	3.5
Townsville	Australia	743	11	26	42	31	66	2673	3.4

Considerations for Artificial Weathering of High Durability Materials

In order to quantify the durability of a material sufficiently well to make a judgment on its expected service-life, one needs to expose the material until failure.

This can be an issue for structural glazing systems designed to provide sustained performance over the course of decades.

Requires long test times, high test stresses or possibly both.

Total Radiant Exposure for Equatorial facing Vertical Exterior

9180 kJ/m^2/nm roughly equates to 3-5 years

20 years roughly equates to 35,000-60,000 kJ/m^2/nm

Long Term Comparative Artificial Weathering Study: Exposing to Failure

System	Prime	Bond Thickness
2-Part Structural Silicone Glazing*	No	9.5 mm
Acrylic PSA Structural Glazing Tape	Silane	2.3 mm

* Reference – 20 year Glazing Adhesive

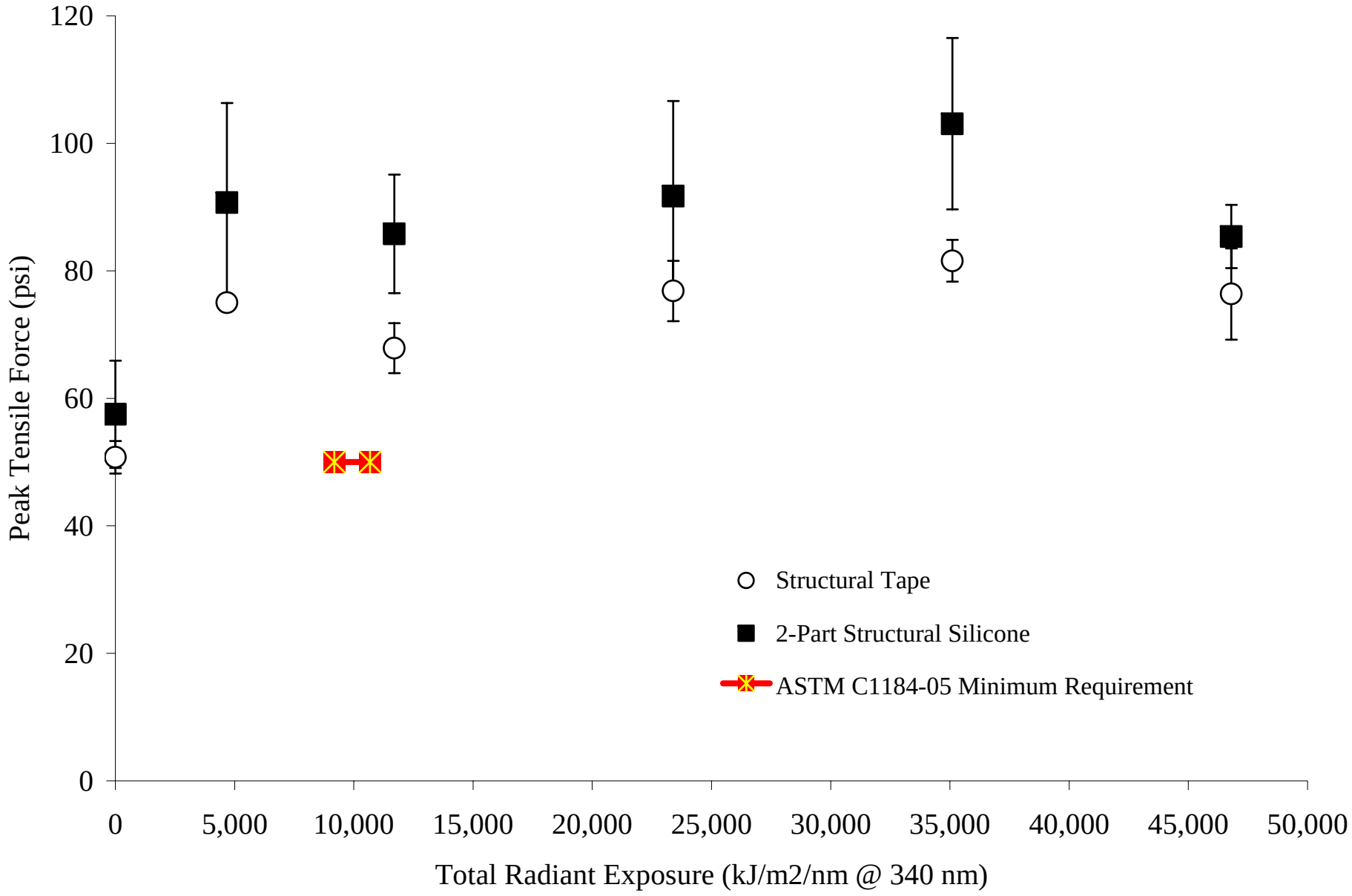
- Clear float glass (¼ in thick) bonded to Black anodized aluminum
- 1 in x 1 in bonded area w/ 4 lineal inches of edge exposure
- High Irradiance Xenon Arc w/ daylight filters (~3X)

  @ 70°C BPT; 102 min Light/18 min water spray
- Tensile & Overlap Shear –0.5 in/min Rate of Pull (ASTM C1184-05)

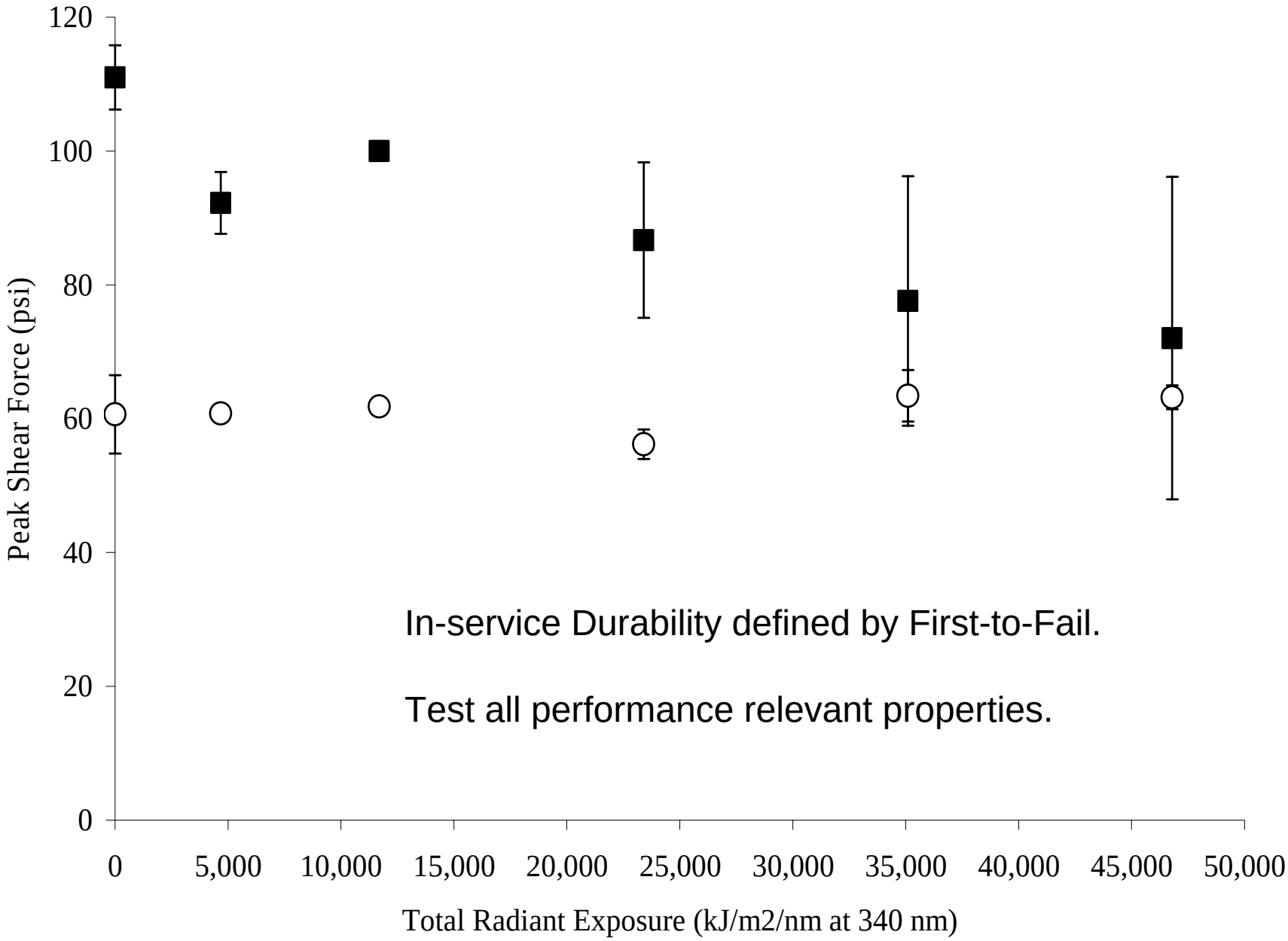
Total Radiant Exposure to date = 46,800 kJ/m^2/nm @ 340 nm

Time to date = A couple of years

Tensile Strength versus Exposure



Overlap Shear Strength versus Exposure



In-service Durability defined by First-to-Fail.

Test all performance relevant properties.

Relating Artificial Weathering Testing to Service Life Estimation of Structural Glazing Systems

Conclusions & Recommendations

- For the industry to develop new and improved systems – in terms of performance as well as reducing construction and repair costs – more service life relevant test methods are needed for evaluating long term durability.
- ASTM C1184-05 radiant exposure required (9180 kJ/m2/nm -> roughly 3 to 5 years of vertical exposure) provides little information for estimating the very long term service life of new systems, which at the end of the day is the parameter engineers are interested in quantifying.
- Longer duration and/or higher irradiance exposures may still not induce failure. However, they considerably increase the confidence a material will maintain its functional properties long term.
- Action needs to be taken on the development of a “performance-based” (i.e., application centric vs material centric) specification for structural glazing systems.
- Such a “performance based” specification should settle on a single protocol for conducting the artificial accelerated weathering and require a good approximation of daylight (i.e, Xenon Arc).