ATLAS
MATERIAL TESTING SOLUTIONS

AMETEK®
MEASUREMENT & CALIBRATION
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New Advancements In Artificial Weathering Testing

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New Advancements In Artificial Weathering Testing

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Sales Manager

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Fundamentals of Weathering

LIGHT – Artificial weathering methods that provide the closest simulation to the full solar spectrum can provide the best correlation

TEMPERATURE – Plays a critical role in degradation rates and is important to know for service life prediction and acceleration rates

WATER – An important factor of weathering, especially to initiate certain physical failures in polymers (especially in combination with light and temperature)

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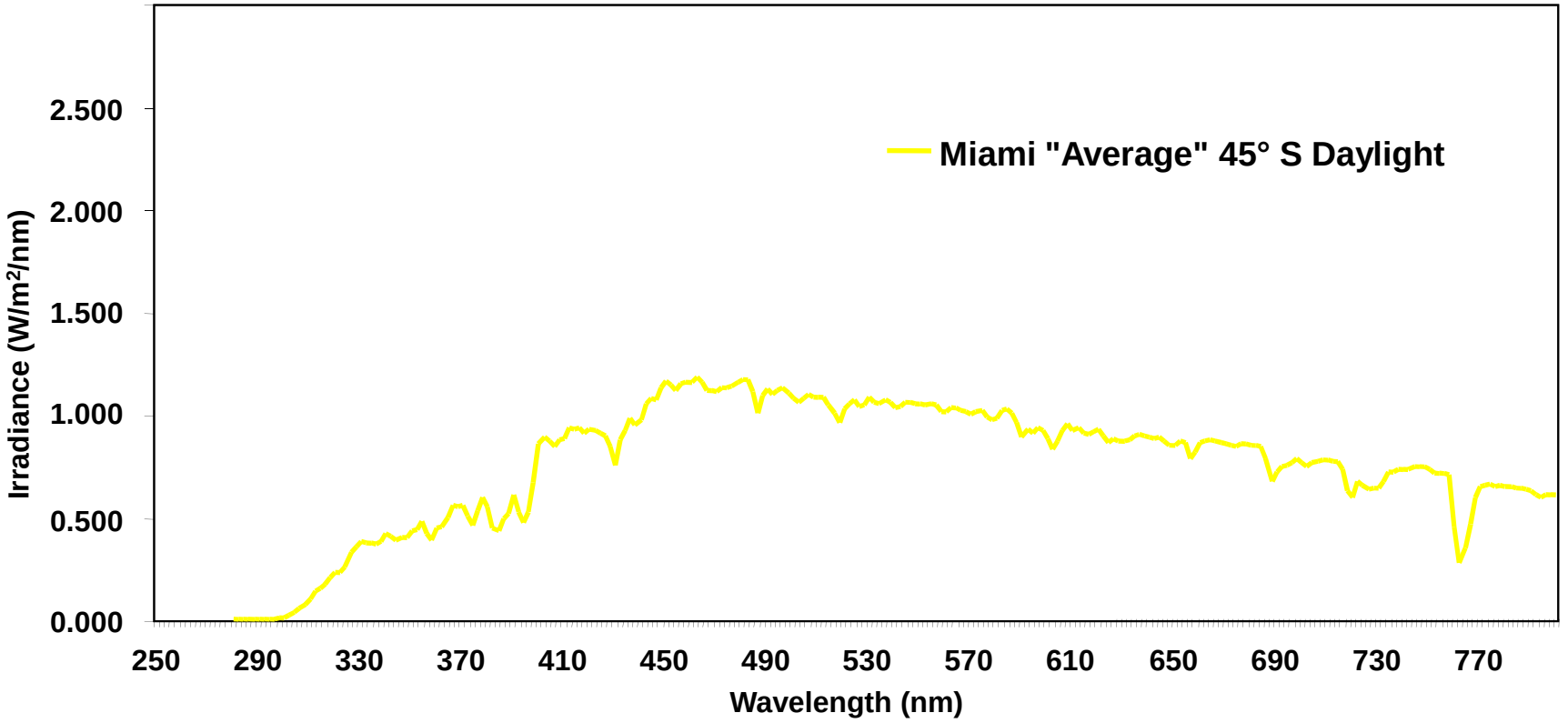
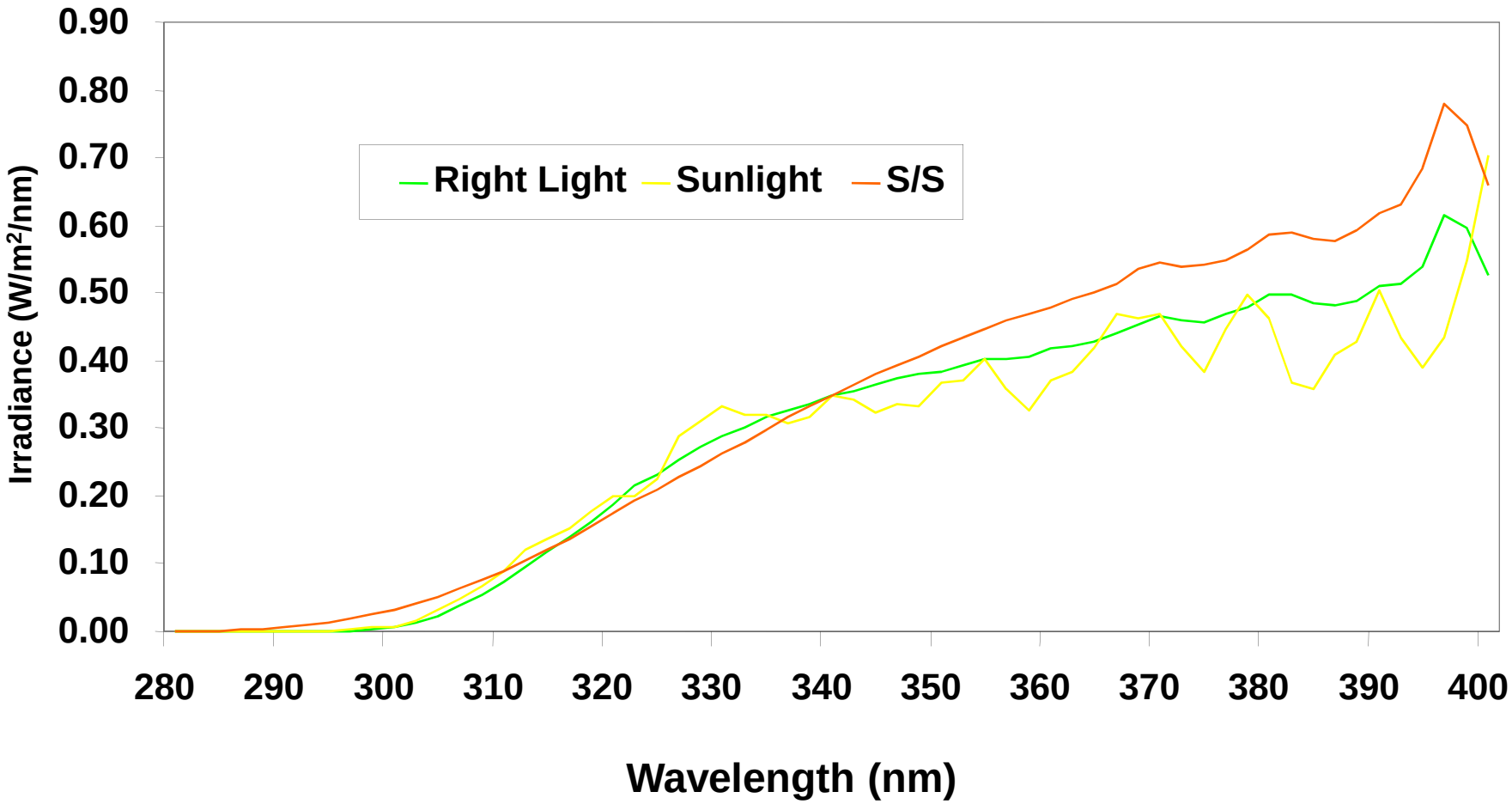
Spectral Power Distribution



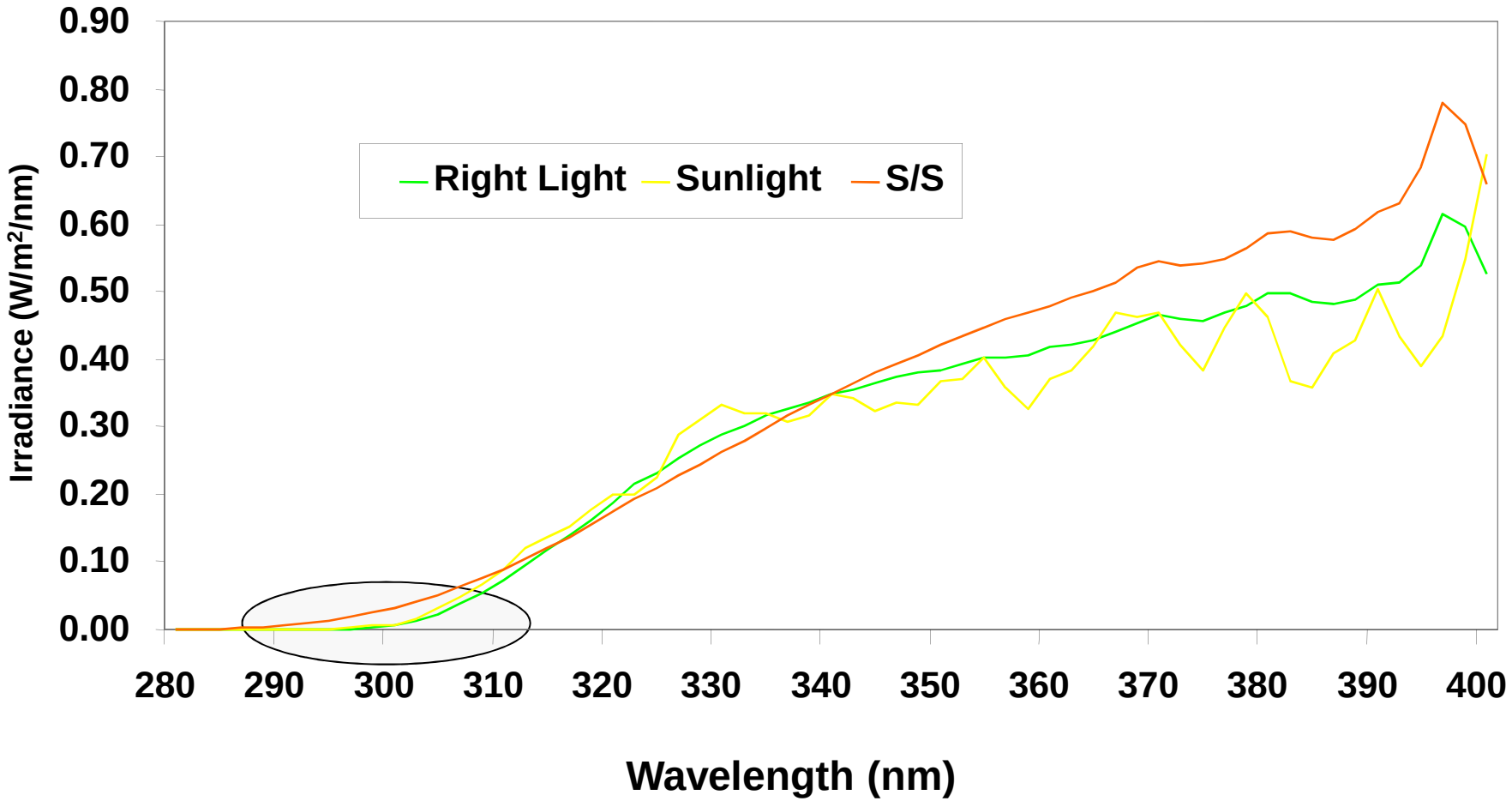
Traditional Xenon Filter Combinations

ISO 4892-2 Designation	Water-cooled Xenon Filters	Air-Cooled Xenon Filter System)	Application
Extended UV	Quartz/Type S Borosilicate	N/A	Historical use in automotive standards with water-cooled xenon
Daylight	Type S Borosilicate/ Type S Borosilicate	Xenochrome 300	Common filter used for standard weathering tests
Daylight behind window glass	Type S Borosilicate/ Soda Lime	Xenochrome 320	Commonly used for lightfastness tests on textiles

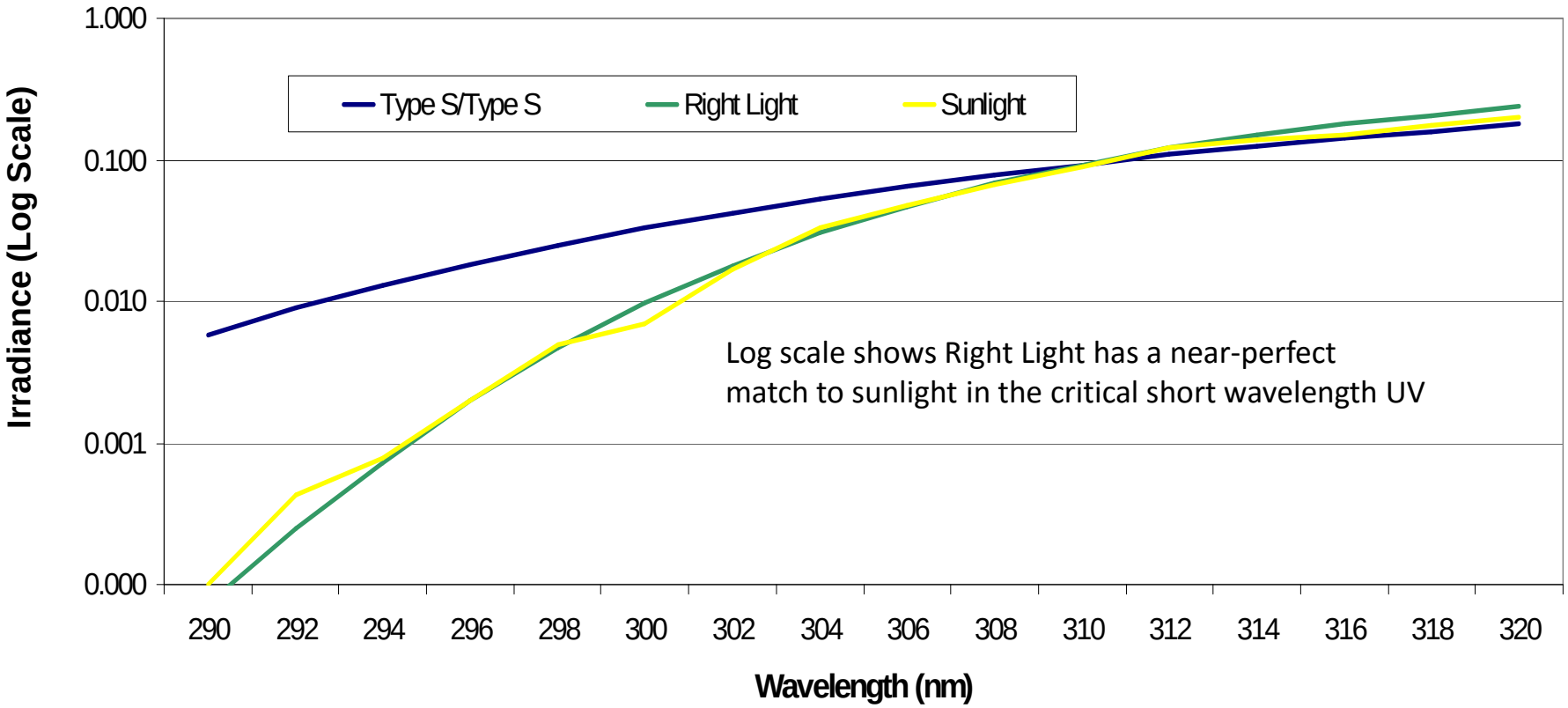
Right Light® Filter System



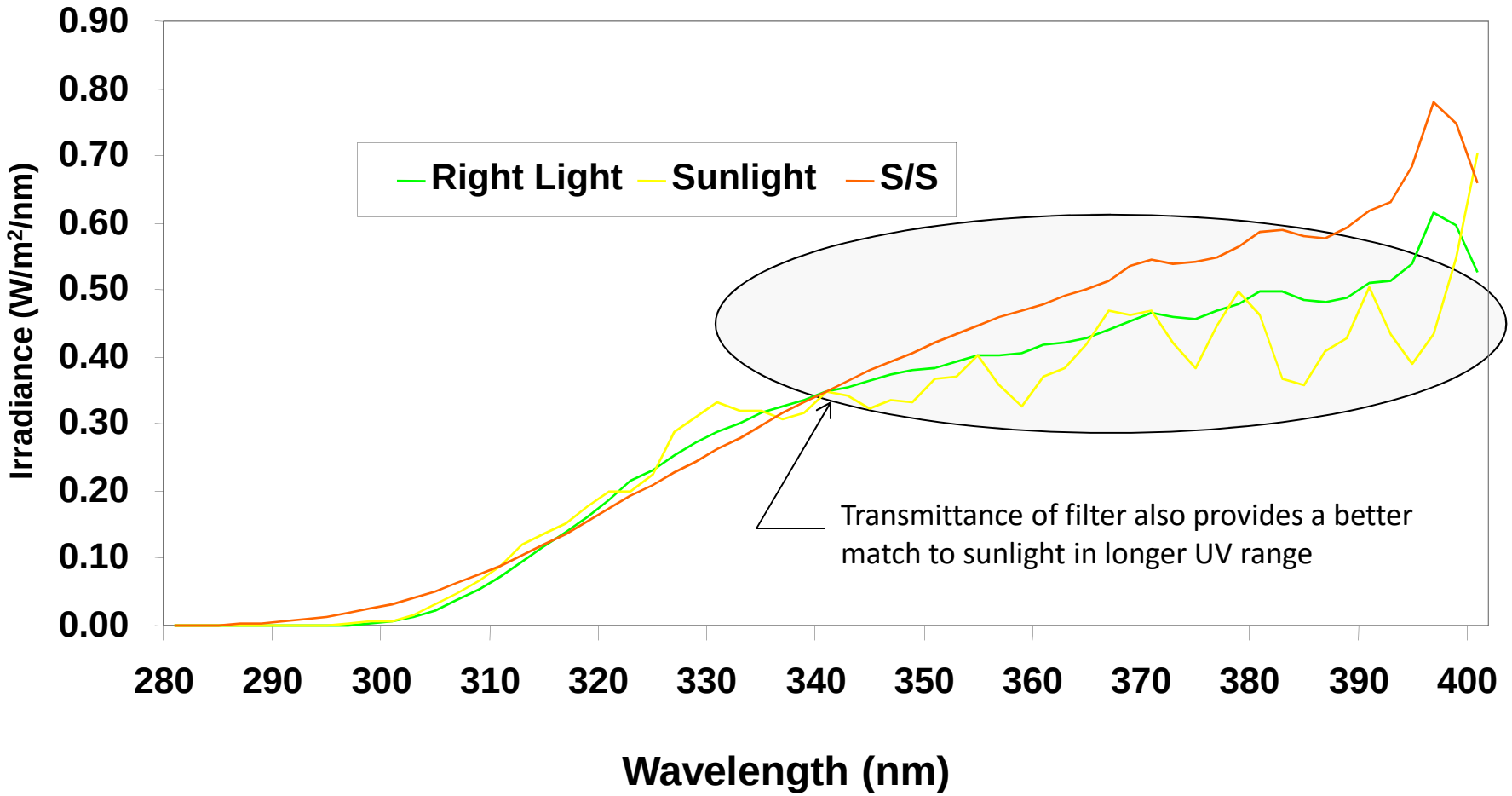
Right Light® Filter System



Right Light® Filter System (log scale)



Right Light® Filter System



Comparison of “Daylight” Filters

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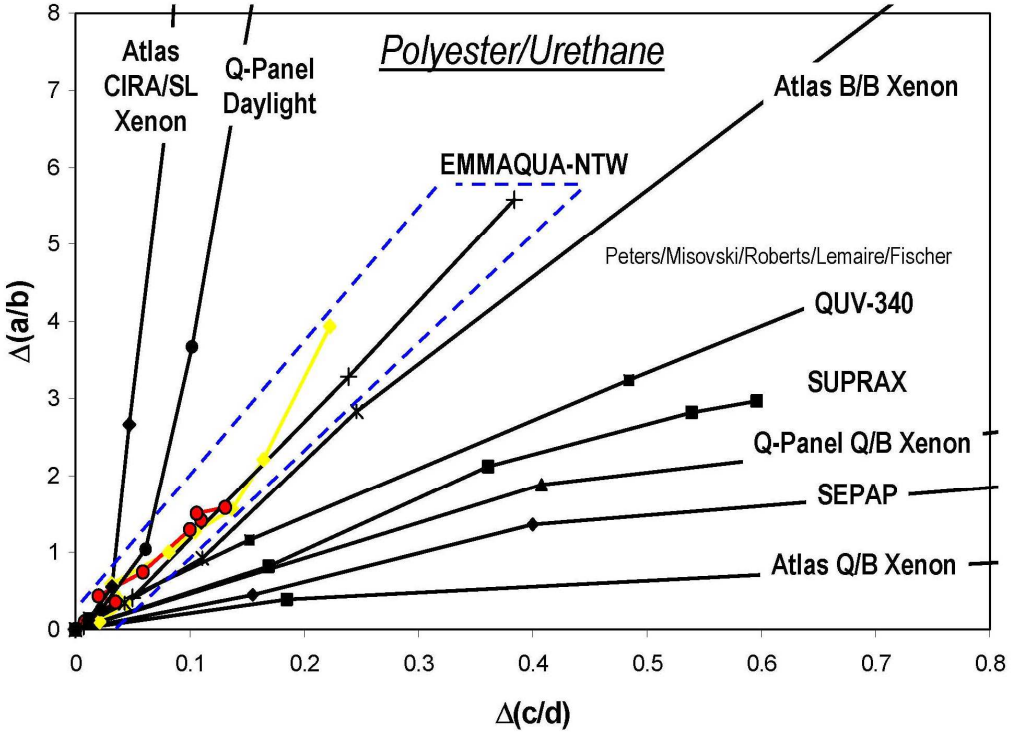
• Ratio plots of specific FTIR chemical marker peaks compare various accelerated systems with various spectral power distributions (SPD) to outdoor exposures. All skewed the photochemistry (except for Emmaqua – an outdoor accelerated test method.

• Critical need to “Get the light right” in accelerated tests to reproduce the photochemistry. None of the existing artificial weathering systems match target SPD well enough.

- Arizona exposure
- So. Florida exposure

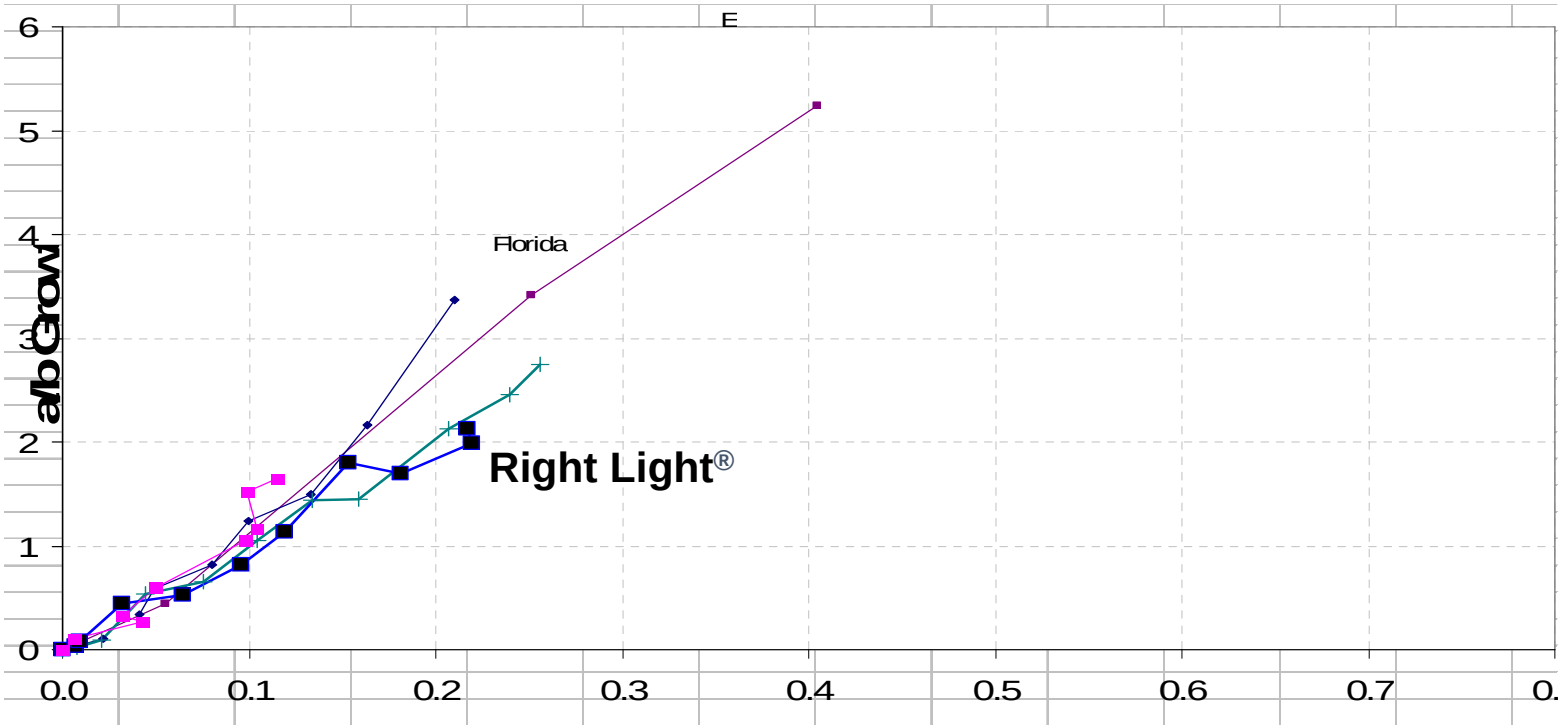


Data courtesy of Dr. Mark Nichols, Ford Motor Company
ATCAE Conference, Oxford, UK

Right Light® Filter System

Xenon light used in conjunction with the Right Light® filter provides the appropriate ultraviolet spectrum for weathering of today's complex automotive coatings."

Mark Nichols
Ford R&D, Exterior Coatings
Quoted in Atlas Sunspots, Vol. 38, Issue 81



Data courtesy of Dr. Mark Nichols, Ford Motor Company
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Summary of Right Light®

- Best match to natural sunlight cut-on wavelength
- Better match to longer UV as well
- Better aging performance – no intermediate filter changes
- Transmittance at 340nm higher than Type S Boro/ Type S Boro
  - *Lower power required to meet same irradiance level*
  - *Lower power = lower operating costs*
  - *Higher irradiance possible for faster testing*
- Meets all “Daylight” specifications

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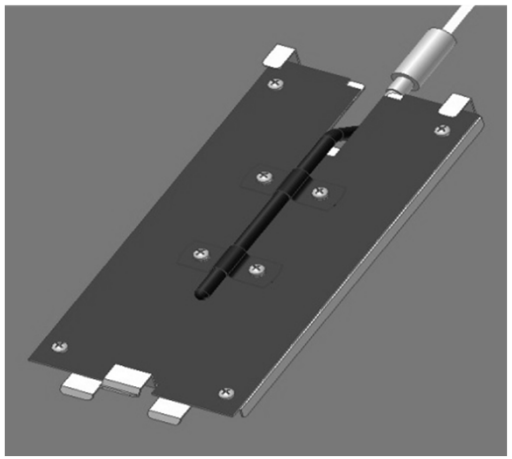
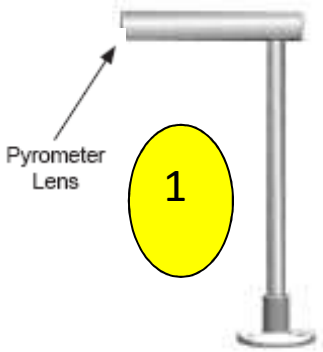
Importance of Temperature

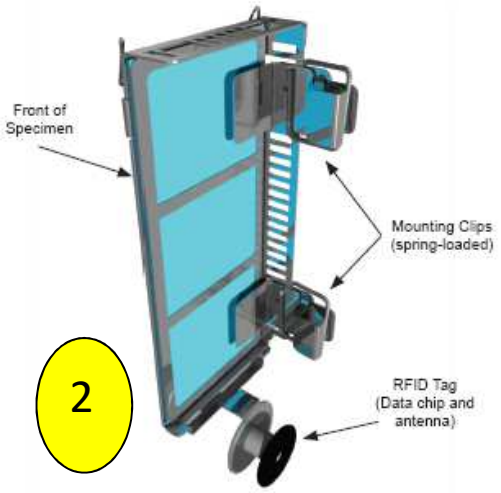
- It is suggested by the “rule of thumb” that reaction rates double for every 10°C increase in specimen temperature.
- Actual degradation rate increases are material dependent
- Degradation for service life prediction calculations is a function of:
  - UV sensitivity; Specimen Temperature; Moisture effects
- Specimen temp varies with color/construction
- Despite its importance, specimen temperatures have not been typically measured in weathering tests
- Black Panels are used to estimate worst-case surface sample temperature
- Problem – Actual specimen temperature is unknown

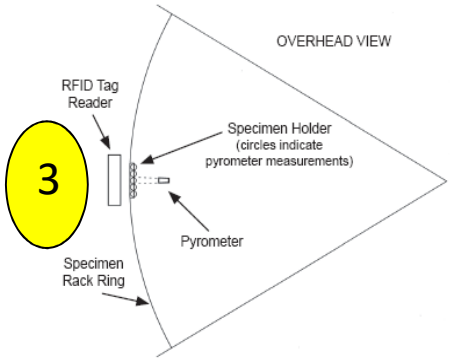


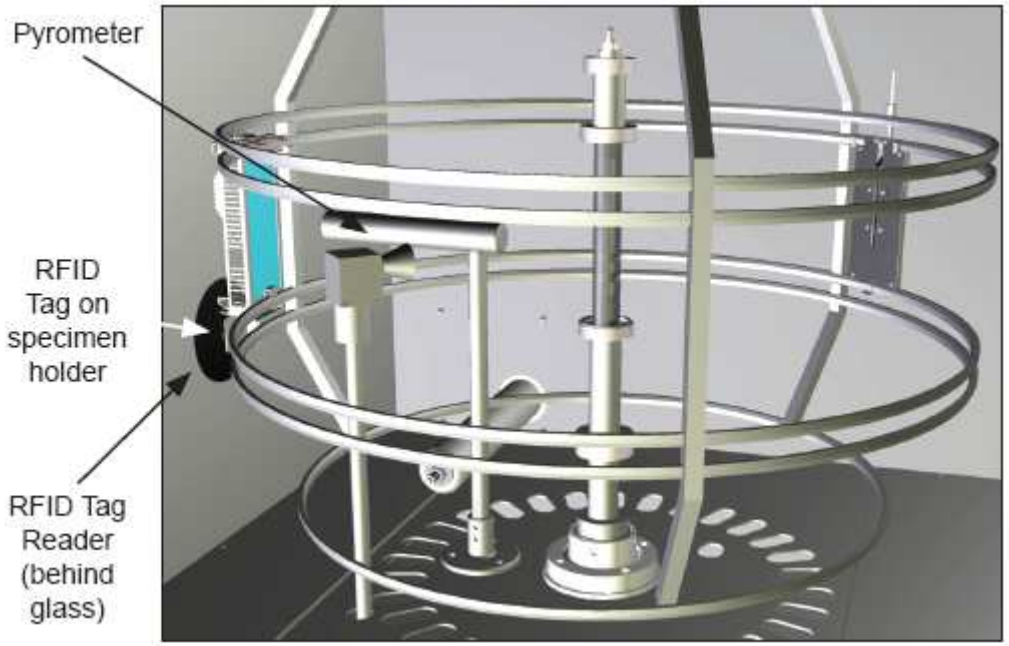
Black Panel Sensor

Specific Specimen Surface Temperature (S³T)









1. Specimens Rotate Around Stationary IR Pyrometer
2. IR Pyrometer Takes Temperature Reading ever 0.2 seconds
3. RFID Reader Identifies Each Specimen Center Position
4. Software Links Specimen Center With IR Pyrometer Reading

S³T User Interface Screens

Magnify

Scroll

To Table

S³T Trend Plot has typical graphing functionality

S³T User Interface Screens

S³T Monitor shows temperature data of all specimens with tag

Summary of S³T

- Integrated into Weather-Ometer controls;
  - *May be operated in with/without S³T activated*
- Automatic sample indexing using RFID
- Sample codes can be entered into software
- Only samples on center tier can be measured

- Temperatures can be viewed on User Interface in table or graph form
- Data transferable to Excel (or other spreadsheet file).
- Calibration traceable to nationally recognized standards body
- Only customer specimen monitoring/recording (no control)

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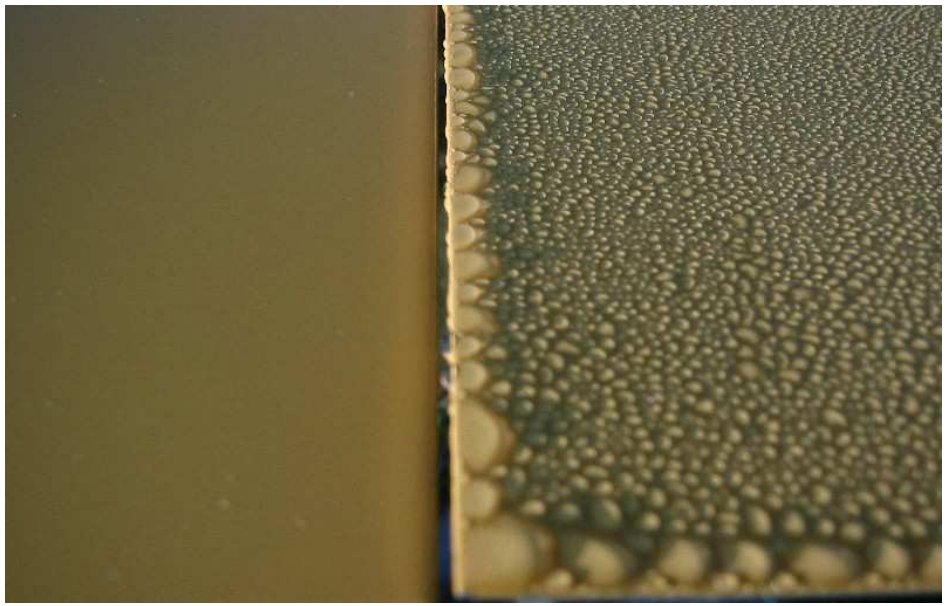
Moisture Matters!!

Effects of Moisture on Weathering

- Absorption / desorption – swelling / shrinking result in mechanical stresses
- Blistering – localized swelling and rupture
- Adhesion – accumulation of water at interface, breakdown of interfacial bonds
- Chalking – hydrolysis resulting in migration of e.g. TiO_2 to the surface of the products
- Mass transport – movement of small molecules and reaction products through film (migration)
- Mass loss – removal of film (degradation products) from surface of the coating due to erosion
- Plastication – reduced elasticity

Dry panel (moisture wiped off)



Panel exposed in South Florida in early morning

Photo courtesy of H.K. Hardcastle

SAE J1960 (Now J2527)

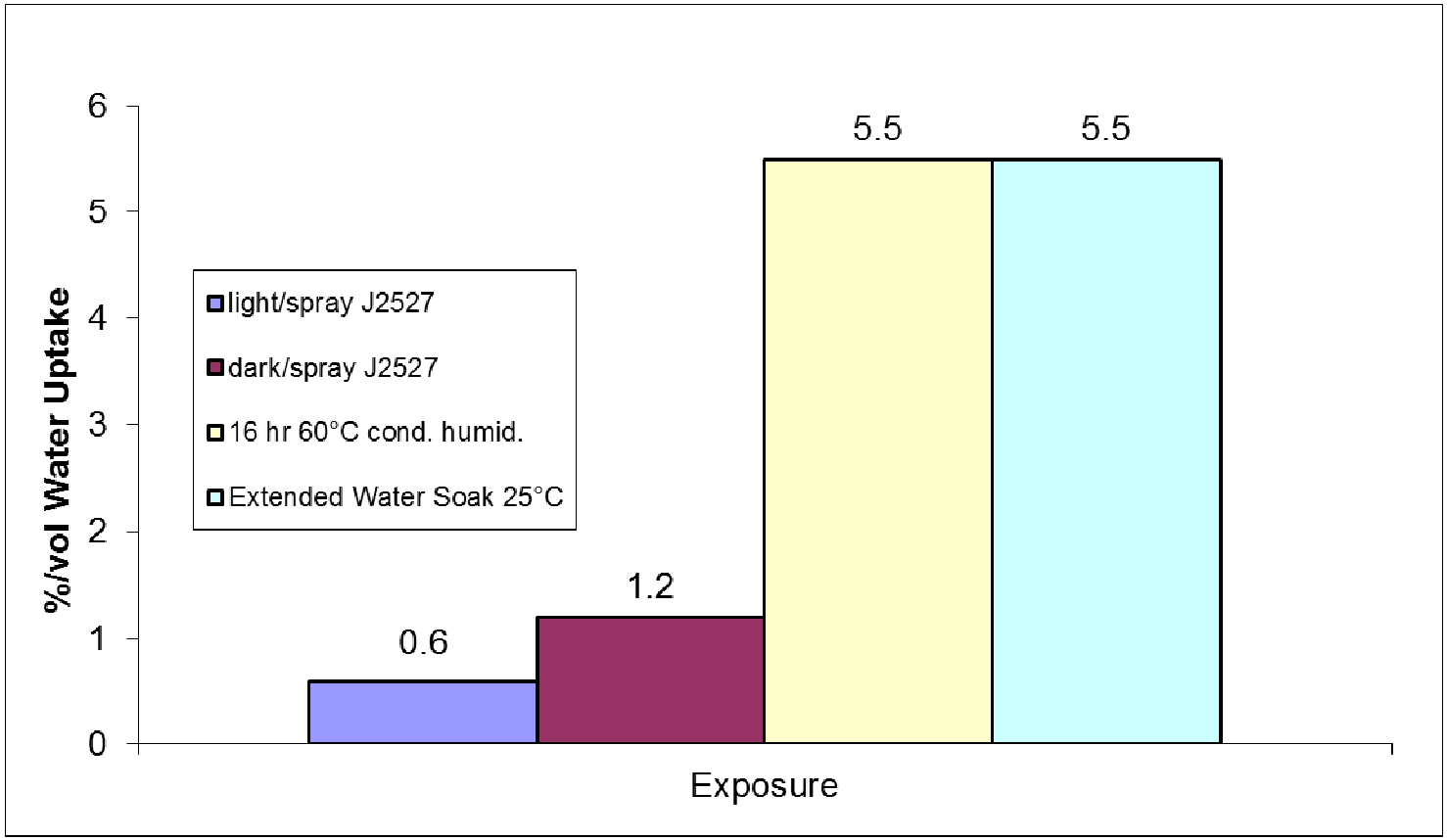
- For over 20 years, this method (under various names) has been the primary standard for many automotive exterior materials
  - *Mid 1980's – original test method development*
  - *SAE J1960 (1989) standard using "extended UV" filters; UV more severe than sunlight (lower UV cut-on λ ~270nm)*
  - *Late 1990's - Ford adopts a "modified" SAE J1960, using "Daylight" filters – less unrealistic UV (cut-on ~285nm)*
  - *2004 – SAE J2527 replaces J1960 – "Performance-based version" with choice of "extended UV" or "daylight" filters, but still excessive UV*

Step#	Water Spray	Irradiance (W/m^2 @340 nm)	Humidity %	Chamber Temperature (˚C)	Black Panel Temperature (˚C)	Duration (minutes)
1	Off	0.55	50	47	70	40
2	Front	0.55	95	47	70	20
3	Off	0.55	50	47	70	60
4	Front/Back	0	95	38	38	60

Frequent lack of correlation with South Florida 2 & 5 year results

- Any "102-18" cycle, such as ISO 4892-2 has the same problems

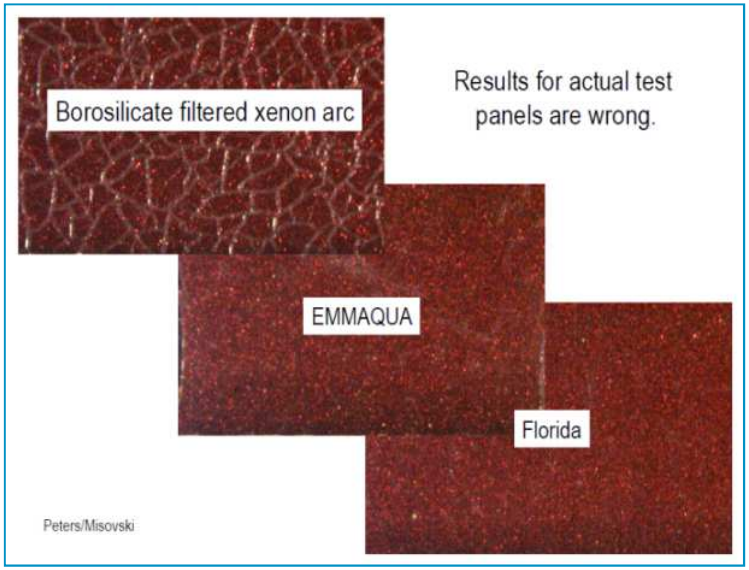
Moisture Cycle of SAE J2527



Graph courtesy of Nichols et al.

Baseline test method evaluation showed SAE J2527 spray cycles not effective in providing moisture uptake seen in natural exposures

Accelerated Weathering vs. In-Service Performance



What is Wrong with the Current Tests?

- Light source – output from lamp/filters does not match sunlight
- Temperature – water spray when the light is on
- Time of wetness – panels are wet for a long time outdoors
- Humidity – rarely reach temperature/humidity conditions outside

Source: M.Nichols, *et al*, "Accelerated Weathering of Automotive Coatings: Exposure Conditions and Analysis Methods", Atlas Technical Conference on Ageing in the Environment, Oxford, UK, September, 2008.

ASTM D7869 Test Cycle

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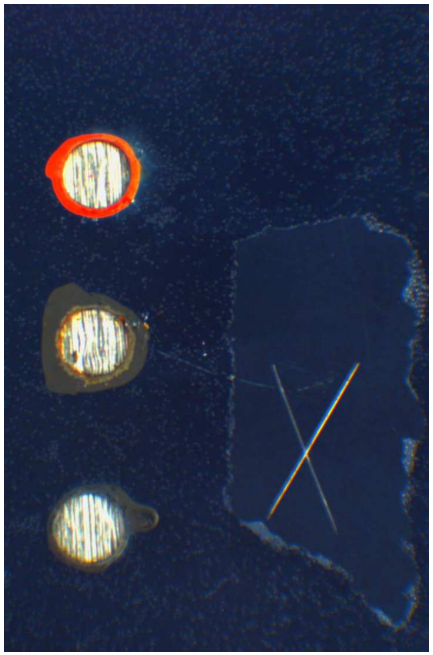
AFTER OVER 10 YEARS OF TEST METHOD DEVELOPMENT WORK…

Step Number	Step Minutes	Function	Irradiance Set Point[1] @340nm ($W/m^2/nm$)	Black Panel Temperature Set Point[1]	Chamber Air Temperature Set Point[1]	Relative Humidity Set Point[1]
1	240	dark + spray	-	-	40°C	95%
2	30	light	0.40	50°C	42°C	50%
3	270	light	0.80	70°C	50°C	50%
4	30	light	0.40	50°C	42°C	50%
5	150	dark + spray	-	-	40°C	95%
6	30	dark + spray	-	-	40°C	95%
7	20	light	0.40	50°C	42°C	50%
8	120	light	0.80	70°C	50°C	50%
9	10	dark	-	-	40°C	50%
10	Repeat steps 6-9 an additional 3 times (for a total of 24 hours = 1 cycle)					

- Longer dark/spray cycles to achieve moisture uptake levels (saturation)
- Multiple irradiance levels to simulate outdoor conditions; High level increases acceleration
- No light/spray together…it doesn't typically rain in max sunshine conditions
- Interspersed light/dark sub-cycles to simulate thermal shock effect occurring in natural exposures

Test Method Development Results

Florida Exposure



SAE J2527

ASTM D7869

Courtesy of Nichols et al.

Example of adhesion test showing correlation to Florida exposure (clear coat delamination in less than two years) while SAE J2527 test indicated a “false positive”

Test Method Development Results

Florida Exposure

SAE J2527

ASTM D7869

Graph courtesy of Nichols et al.

Example of correlation of good weathering performance as well as accelerated weathering methods

Summary of ASTM D7869

- Traditional automotive exterior test methods (SAE J2527 or „102-18“ cycles) have weaknesses that result in lack of correlation
  - *Spectral Power Distribution incorrect*
  - *Moisture cycles not long enough to cause saturation*
  - *Spray with light phase isn‘t „real“*
  - *Not accelerated as much as possible with current instrument technology*
- Over 10 years of test method development resulted in a new complex test method that simulates So. Florida climate
- Results on automotive and aerospace coatings can provide better correlation and increased acceleration
- Adopted and published as ASTM standard
- Ongoing evaluation by several European automotive OEMs

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Thank You!!!