Automotive Interior and Exterior Weathering Testing

Presented by Q-Lab

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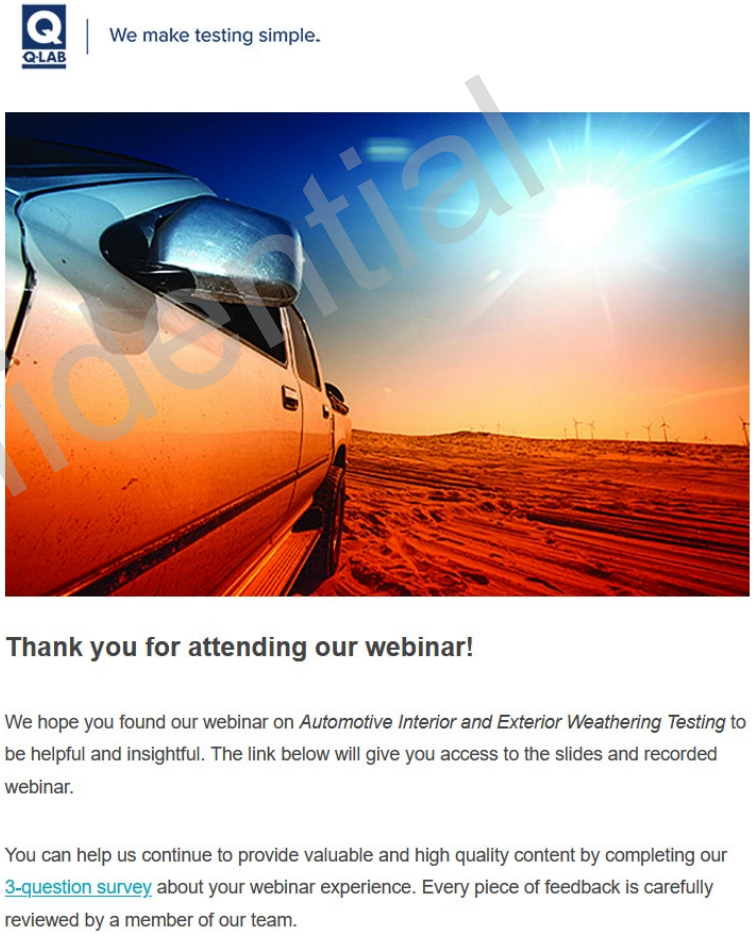
Q-Lab's Weathering Webinar Series

- Today is the first of our five-part webinar series on special weathering testing topics
- Our upcoming and archived webinars are hosted at: q-lab.com/webinars

Date	Topic
14 Apr	Automotive Interior and Exterior Weathering Testing
21 Apr	Modern Automotive Weathering Test: ASTM D7869
28 Apr	Light Stability Testing of Home and Personal Care Products
05 May	Water Delivery in Accelerated Weathering Testing
12 May	Correlation in Accelerated Weathering and Corrosion Testing

Administrative

- You'll receive a follow-up email from info@email.q-lab.com with links to a survey, registration for future webinars, and to download the slides
- Use the Q&A feature in Zoom to ask us questions today! We'll stay on after the presentation is completed to answer all questions



Today‘s Agenda

- Weathering of automotive components
- Weathering science basics
- Natural outdoor testing
- Accelerated laboratory testing
- Automotive test methods

Weathering of Automotive Components

Why is it worthwhile to conduct weathering testing?

Weathering of Auto Exteriors

Color change and gloss loss

Weathering of Auto Exteriors

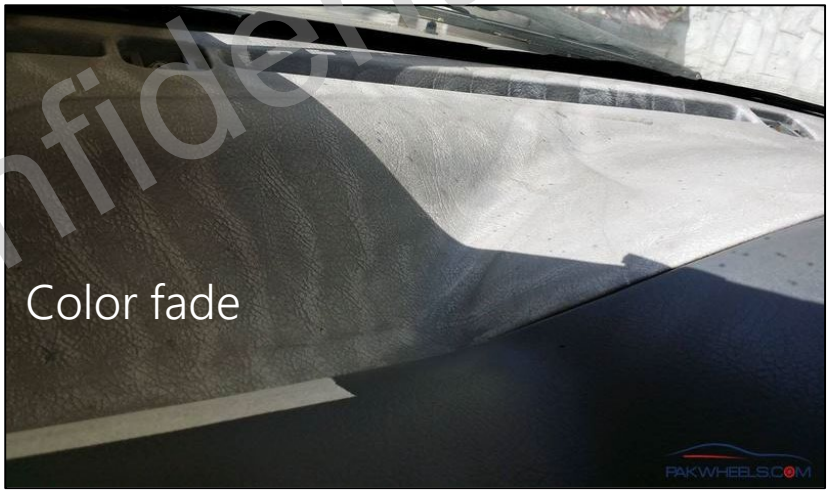
Physical and Chemical failures

Weathering of Auto Exteriors

Physical and Chemical failures

Weathering of Auto Interiors

Physical and Appearance failures



Why Do Weathering Testing?

High gloss and color integrity

OR

Fading, cracking, peeling

Weathering testing can mean the difference between happy customers and … the customer on the right

Weathering Science Basics

Why do interior and exterior automotive components fail in service?

What is Weathering?

Changes in material properties resulting from exposure to the radiant energy present in sunlight in combination with heat (including temperature cycling) and water in its various states, predominately as humidity, dew, and rain.

Forces of Weathering

Know Your Enemy!

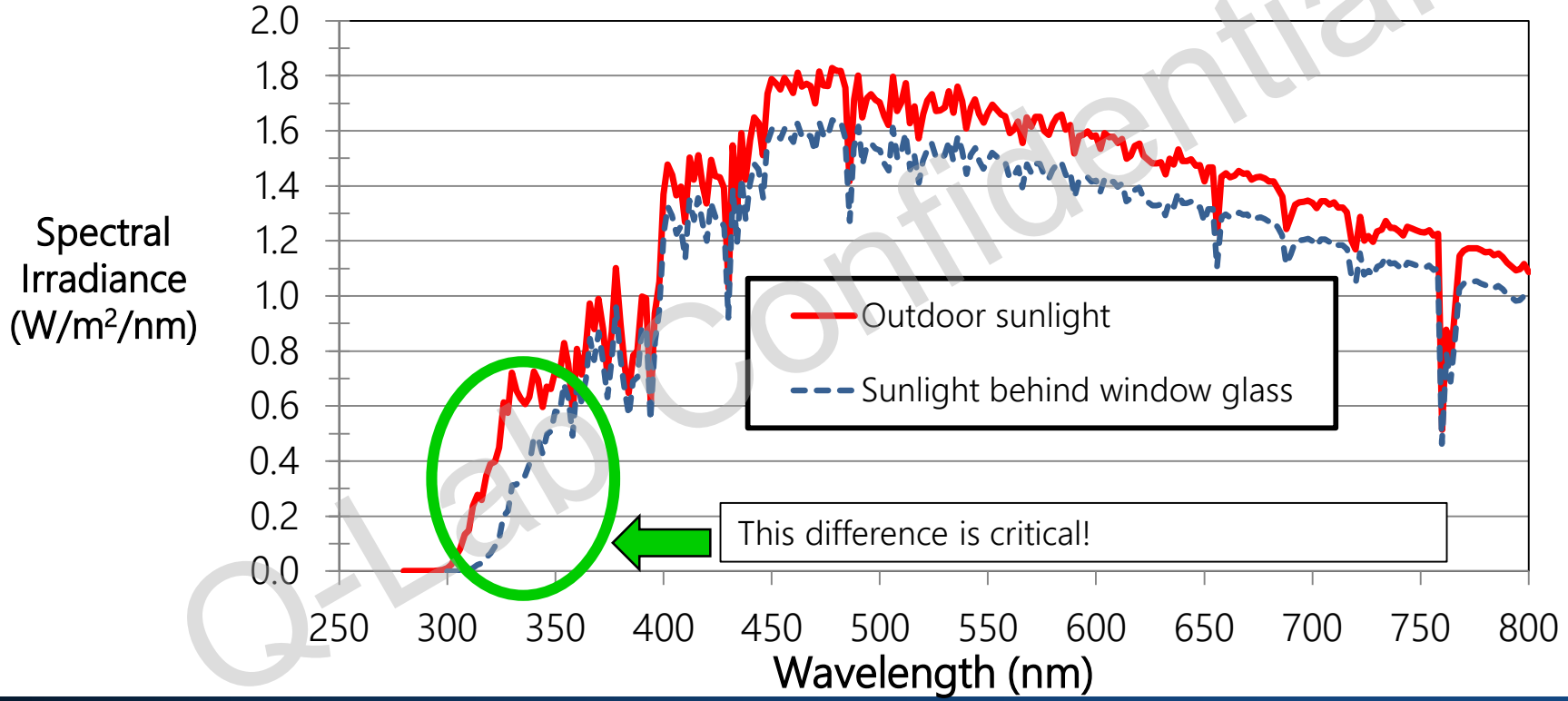
- Sunlight
- Heat
- Water

**Other factors can impact weathering as well but we will not focus on those today*

Ultraviolet (UV) light is responsible for most weathering degradation

UV is only 7% of the sunlight spectrum but it causes virtually all polymer degradation!

Sunlight Exterior vs Sunlight Interior



Factors Affecting Automobile Glass Light Filtering

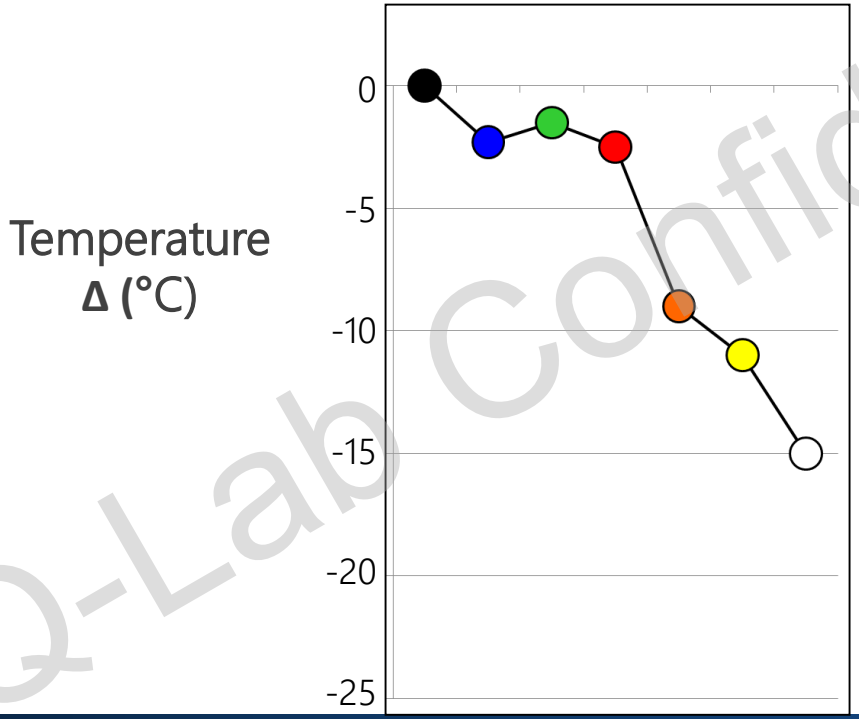
- Tint
- Thickness
- Lamination

Heat Effects

- Dimensional change
- Evaporation
- Thermal aging
- Thermal cycling

Temperature and Color

Darker Colors Have Higher Temperatures!



Heat behind Window Glass

Temperature of automobile interior components behind window glass can exceed 100 °C

Major Effects of Water

- Chemical Reactions
  - Reactions in solution
  - Facilitates reaction via increase in oxygen transport

- Physical Effects
  - Erosion
  - Absorption/freeze-thaw
  - Thermal shock
  - Impact (material loss)

Water in Service Environments

Humidity

- Affects time of wetness
- Exterior and interior

Rainfall

- Washing of surfaces
- Chalking
- Thermal shock

Dew

- High O_2 content
- Long dwell time

PRIMARY SOURCE OF OUTDOOR WETNESS

Natural Outdoor Weathering Testing

Benchmark test data from realistic exposures

45° south-facing exposure

0° Exposure Angle

Mesh backing for three-dimensional components

Black Box Testing

- Imitates auto trunk and hood conditions
- Developed by GM in 1950's
- High temperature
- SAE J1976

Under-Glass Exposures for Interior Components

Whole Car Testing

- Testing of entire vehicle
- Best simulation of the end use – includes exterior and interior weathering
- All parts, materials and components interact during the weathering process
- Thermal radiation studies commonly performed

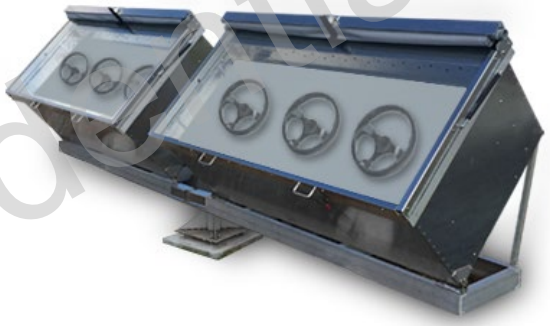
Accelerated Outdoor Weathering Testing

Realistic exposures done faster

AIM Box

“Automotive Interior Materials” Box

- Reproduces extreme heat from automotive interior
- Can test entire instrument panel
- Different plastics experience different thermal expansion
- Generates differential stresses between different interior plastics



Natural Sunlight Concentrator: Q-TRAC

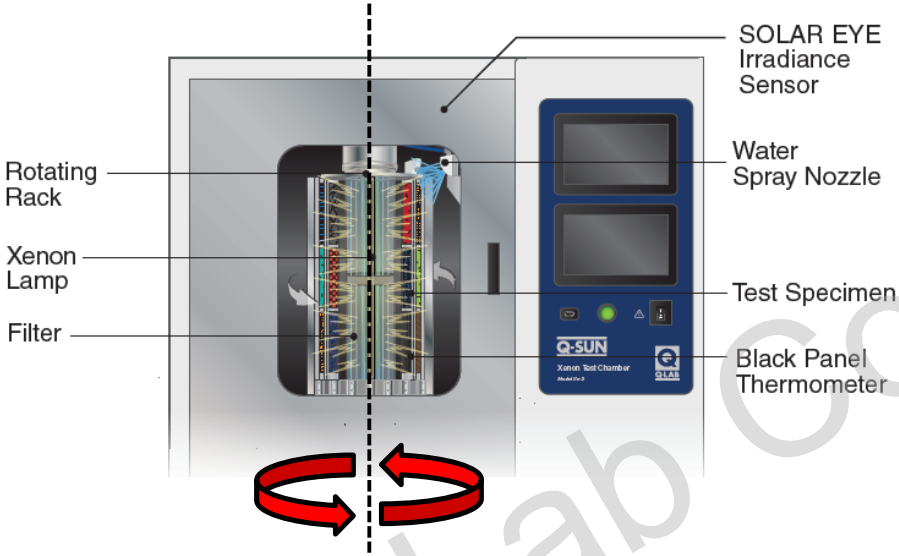
Natural Sunlight Concentrator: Q-TRAC

- Tracks the sun during the day
- Delivers 5 × as much UV as a natural exposure
- Fast results with natural solar spectrum

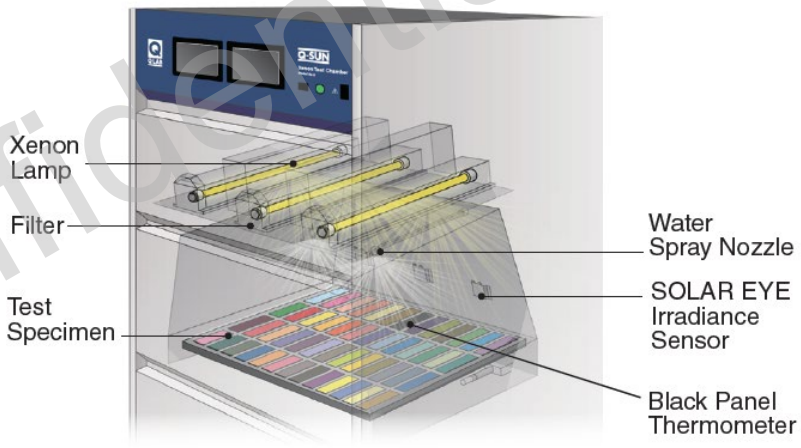
Laboratory Weathering Testing

Accelerating testing for faster results than outdoor

Xenon Arc Test Apparatus



Rotating Drum



Flat Array

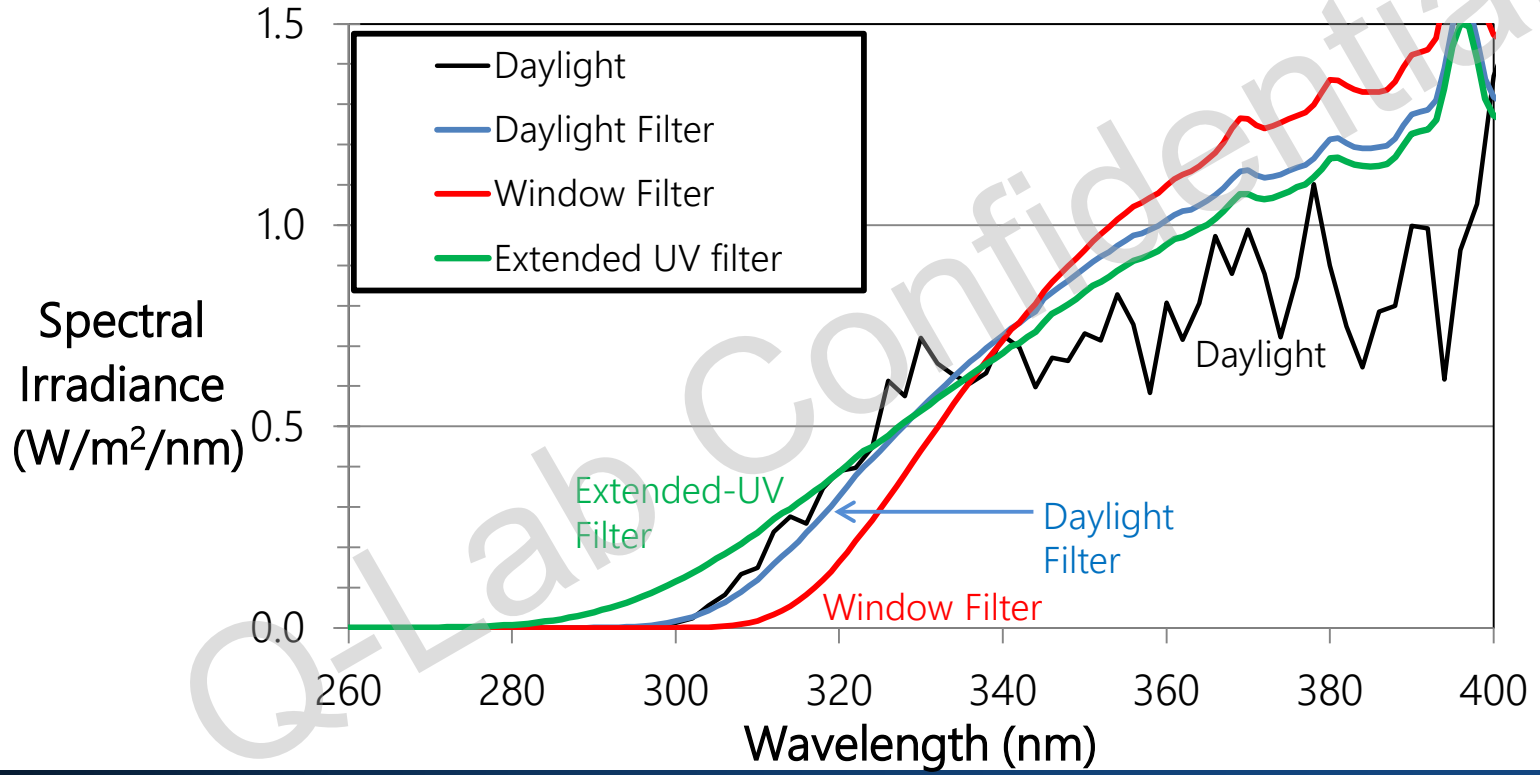
Optical Filters

- **Daylight** (for exterior components)
- **Window** (for behind-glass interior components)
- **Extended UV** (for harsh testing, quality control)

Rotating drum "lantern" filter

Flat array filter

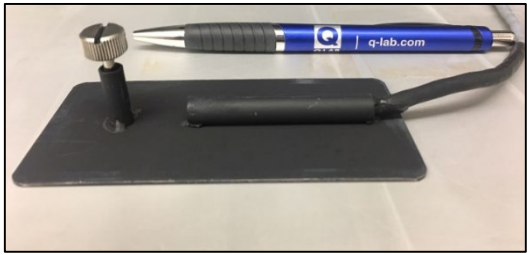
Xenon and Sunlight Spectra



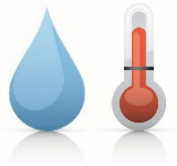
Black Panel Temperature Control

- Most common in test standards
- Approximates maximum specimen surface temperature
- Can be used in combination with chamber air temp sensor and control

Black Panel Temperature Sensors

Panel	ASTM (ISO) Designation	Typical use
	Uninsulated Black Panel (Black Panel)	Metallic substrates (painted metal)
	Insulated Black Panel (Black Standard)	Insulating substrates (polymers)

Environmental Control

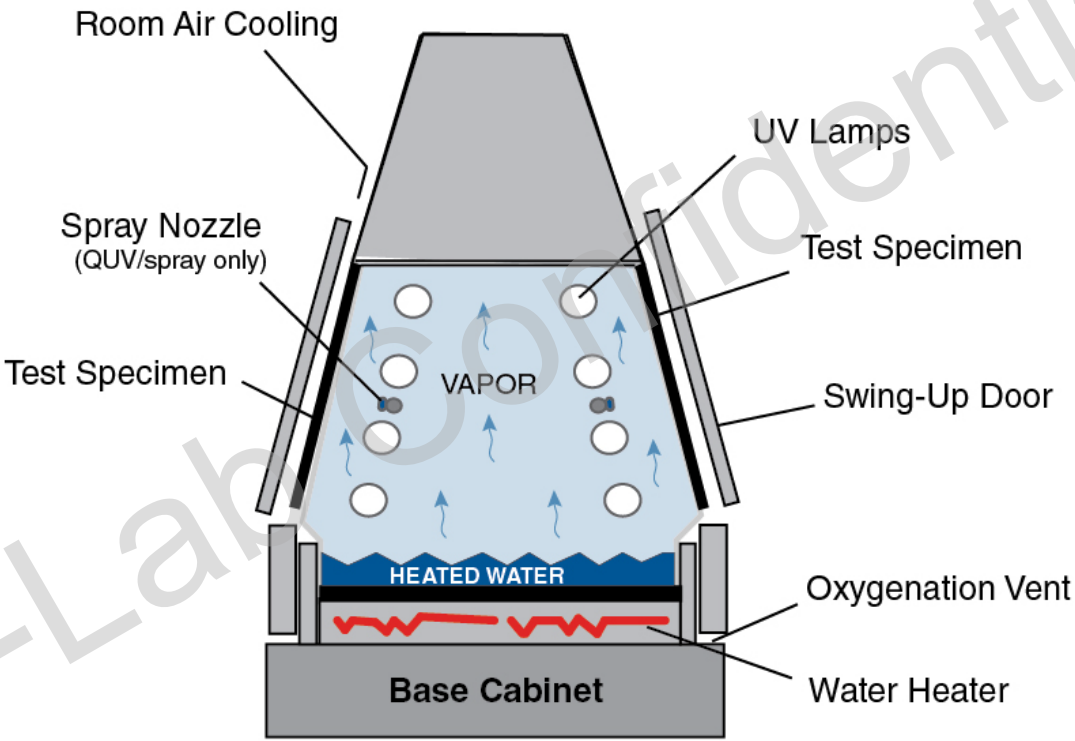


- CAT and RH control Required by certain test methods
- CAT spec necessary for control of RH
- BP temp always hotter than chamber air temp from absorbing radiant heat
- For many durable materials, RH makes very little difference compared to spray and condensation

Xenon Arc Water Spray

- Front spray
  - Primary method of water delivery
  - Calibration technique for front spray recently developed (ASTM D7869)
- Back spray
  - Result of a failed experiment intended to generate condensation; persists in some standards
- Dual spray
  - For delivering a 2nd solution, e.g. acid rain, soap
- Immersion (Ponding)
  - Alternative to front spray called out in some standards

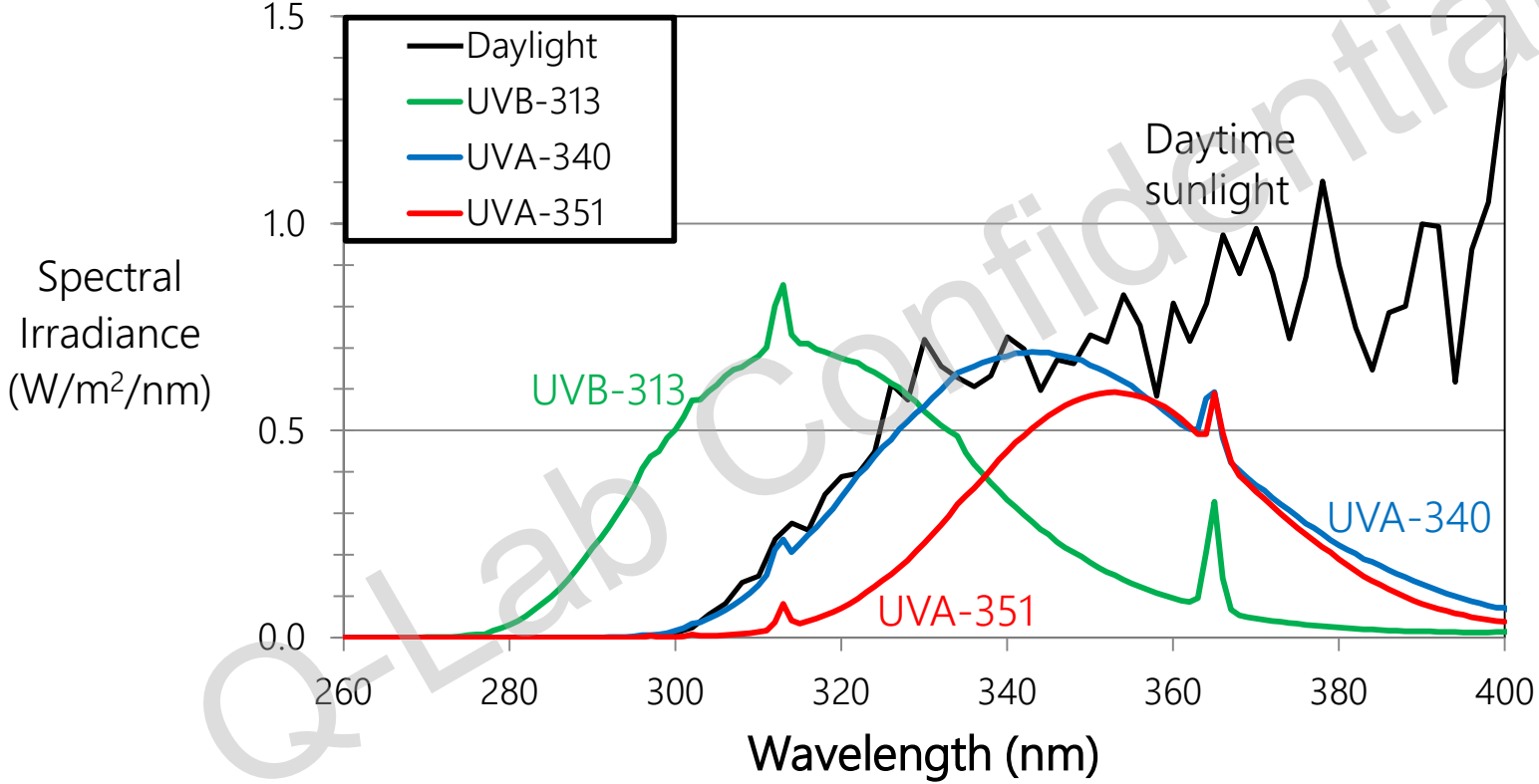
Fluorescent UV Test Apparatus



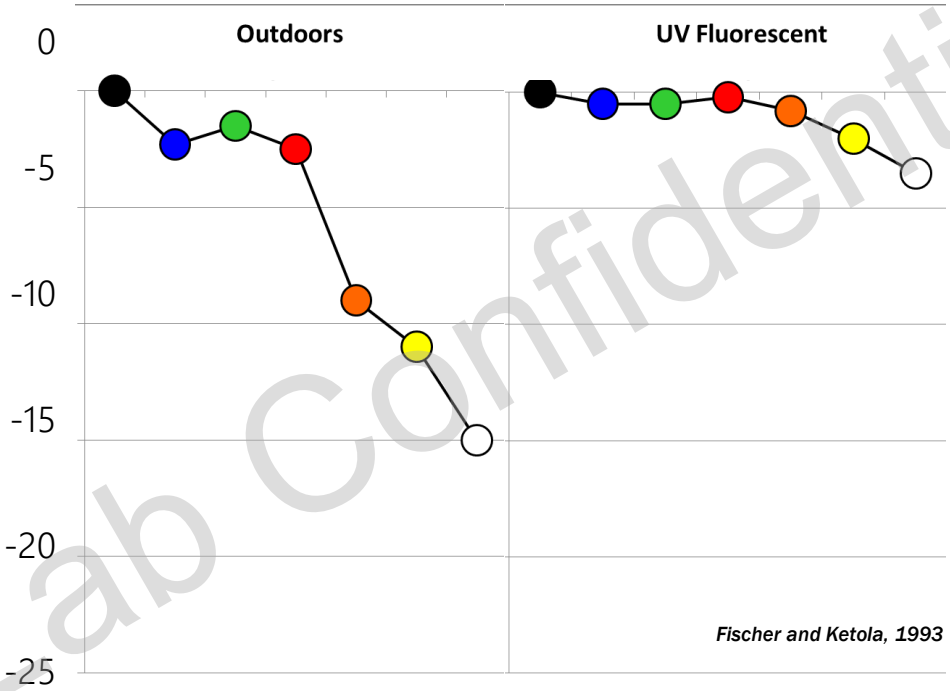
QUV Lamps

- UVA-340 (for exterior components)
- UVA-351 (for interior components)
- UVB-313EL (for harsh testing, quality control)

QUV Lamp and Sunlight Spectra



QUV Color Temperature



- Xenon testers generate IR heat and reproduce outdoor color temp. differences
- UV fluorescent testers do not

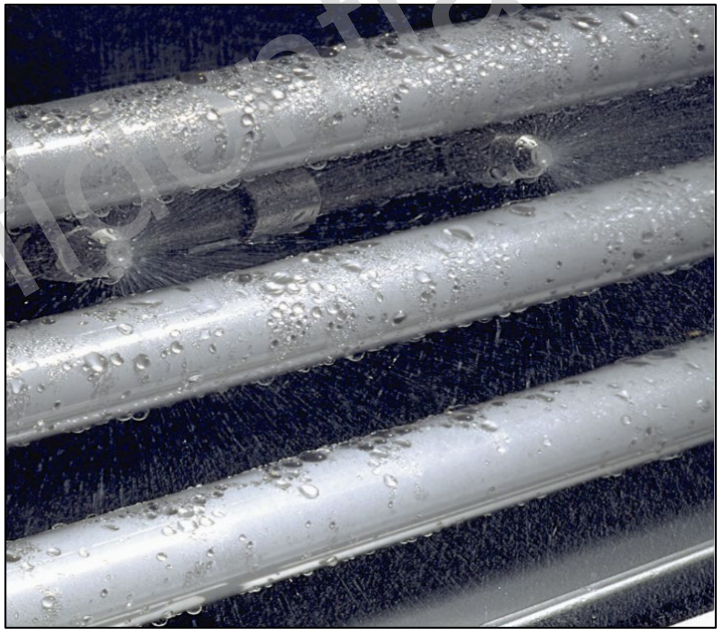
QUV Condensation

- Closest match to natural wetness
- Best way to accelerate water in an laboratory tester
- Elevated temperature
- High O_2 content
- Tester performs distilling – you cannot deposit debris on specimens! Water is guaranteed to be clean.

Creating condensation in the QUV is easy and does not require expensive, pure water

QUV Water Spray

- Ensures that parts get fully saturated
- Creates erosion & thermal shock



Automotive Accelerated Laboratory Testing

Driving towards better correlation with outdoor weathering

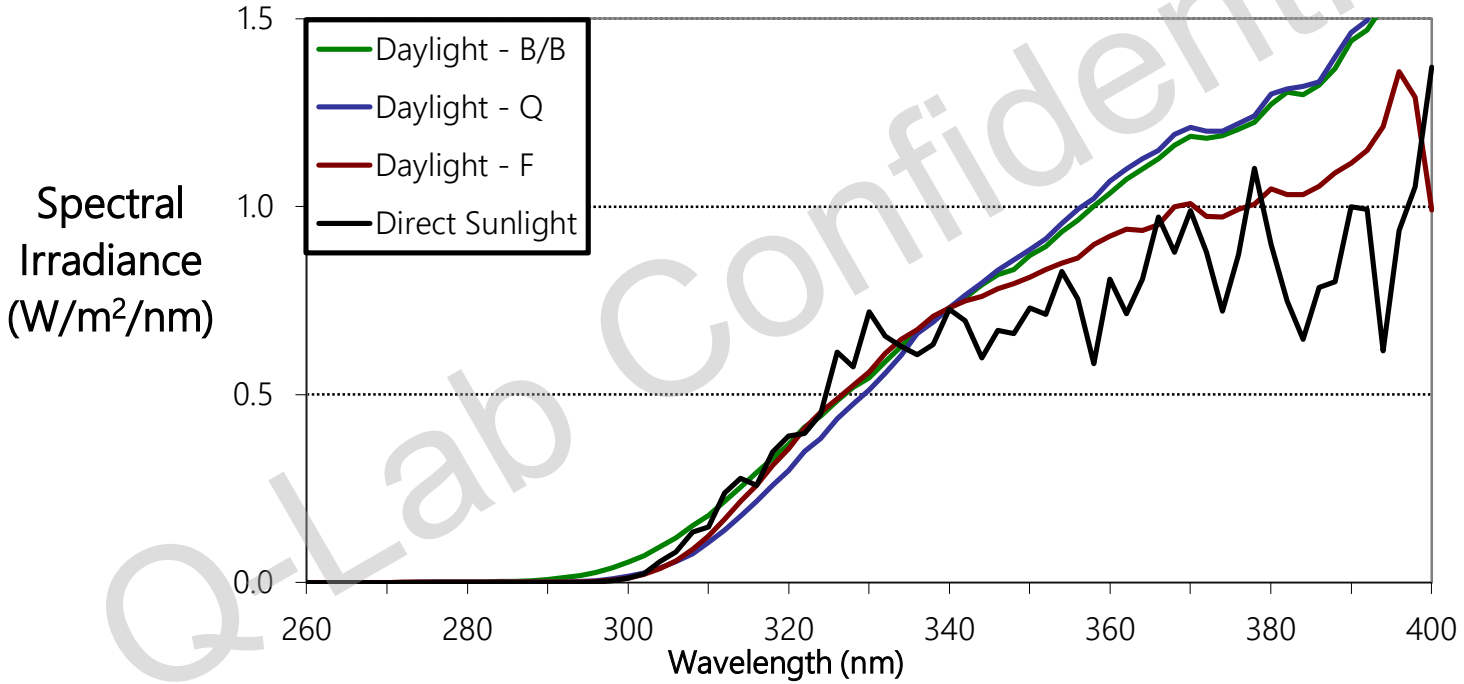
Automotive Weathering Testing

Exterior and Interior Test Conditions Summary

Property	Exterior	Interior
Light spectrum	Daylight / Extended-UV filters UVA-340 lamps	Window filters UVA-351 lamps
Heat	Elevated temperature	Very high temperature
Water	Condensation Water Spray	None
Humidity	Can be controlled; affects time of wetness	Can be controlled; not often critical

Automotive Weathering Testing

Exterior Light Spectra: Which best represents the sun?



Automotive Weathering Testing

Basic Exterior Tests (ASTM)

ASTM INTERNATIONAL

ASTM G154

TABLE X2.1 Common Exposure Conditions

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
1	UVA-340	0.89 W/m²/nm	340 nm	8 h UV at 60 (±3) °C Black Panel Temperature; 4 h Condensation at 50 (±3) °C Black Panel Temperature

Decades of data collected with these tests

ASTM G155

TABLE X3.1 Some Historical Exposure Conditions

Cycle	Filter	Irradiance and Wavelength	Exposure Cycle	Black Panel Temperature (BPT) (°C)	Relative Humidity (RH) (%)	Chamber Air Temperature (CAT) (°C)
1	Daylight	0.35 W/(m²· nm) @ 340 nm	102 min light	63	*50*[A]	*44*[A]
			18 min light and water spray[B]	Uncontrolled		*44*[A]

- **Advantages:** history, general applicability and compatibility
- **Disadvantages:** not scientifically designed, may lack correlation

Automotive Weathering Testing

Basic Exterior Tests (ISO)

ISO 4892-3, 16474-3

Used around the world

Method A: Artificial accelerated weathering with UVA-340 lamps				
Cycle No.	Exposure period	Lamp type	Irradiance	Black-panel temperature
1	8 h dry 4 h condensation	UVA-340 (type 1A)	0,76 $W \cdot m^{-2} \times nm^{-1}$ at 340 nm UV lamps off	60 °C ± 3 °C 50 °C ± 3 °C

ISO 4892-2, 16474-2

Method A — Exposures using daylight filters (artificial weathering)						
Cycle No.	Exposure period	Irradiance[b]		Black-standard temperature °C	Chamber temperature °C	Relative humidity %
		Broadband (300 nm to 400 nm) W/m^2	Narrowband (340 nm) $W/(m^2 \cdot nm)$			
1	102 min dry 18 min water spray	60 ± 2 60 ± 2	0,51 ± 0,02 0,51 ± 0,02	65 ± 3 —	38 ± 3 —	50 ± 10[c] —

- **Advantages:** history, general applicability and compatibility
- **Disadvantages:** not scientifically designed, may lack correlation

Automotive Weathering Testing

Basic Exterior Tests: SAE J2020

Program the Cycle Timer to achieve the following test conditions: 8 h UV light exposure at 70 °C, alternating with 4 hours condensation exposure at 50 °C.

Allows for UVA or UVB lamps

- **Advantages:** history, general applicability, includes water & dark
- **Disadvantages:** still water-deficient; optical filters with excess UV

Automotive Weathering Testing

Popular Exterior Tests: SAE J2527

Step	Light	Dark	Spray
1	None.	60 min.	Front and back
2	40 min/ 1.32 kJ•m^{-2}•nm^{-1}	Not applicable	None
3	20 min/ 0.66 kJ•m^{-2}•nm^{-1}	Not applicable	Front
4	60 min./ 1.98 kJ•m^{-2}•nm^{-1}	Not applicable	None

Not really needed

One of the few tests to define exposure by energy instead of power

- **Advantages:** history, general applicability, includes water & dark
- **Disadvantages:** still water-deficient; optical filters with excess UV

Automotive Weathering Testing

High Irradiance Exterior Tests

ASTM G154

TABLE X2.1 Common Exposure Conditions

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
6	UVA-340	1.55 W/m²/nm	340 nm	8 h UV at 60 (±3) °C Black Panel Temperature; 4 h Condensation at 50 (±3) °C Black Panel Temperature.
2	UVB-313	0.71 W/m²/nm	310 nm	4 h UV at 60 (±3) °C Black Panel Temperature; 4 h Condensation at 50 (±3) °C Black Panel Temperature

Harsh spectrum

High intensity

ASTM G155

This is called a "3 sun" test, popular with Japanese automakers

TABLE X3.1 Some Historical Exposure Conditions

Cycle	Filter	Irradiance and Wavelength	Exposure Cycle	Black Panel Temperature (BPT) (°C)	Relative Humidity (RH) (%)	Chamber Air Temperature (CAT) (°C)
9	Daylight	180 W/m² @ 300 - 400 nm	102 min light	63	50	28[A]
			18 min light and water spray[B]	Uncontrolled		28[A]

- Advantages: *Speed!!!*
- Disadvantages: Correlation

Automotive Weathering Testing

Scientific Exterior Test: ASTM D7869

TABLE 1 Exposure Cycle

Step Number	Step Minutes	Function	Irradiance Set Point[A] at 340 nm W/(m²·nm)	Black Panel Temperature Set Point[A]	Chamber Air Temperature Set Point[A]	Relative Humidity Set Point[A]
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 subcycle steps 6 to 9 (shown in bold) an additional 3 times (for a total or 24 h = 1 cycle).					

Long water

A solar day

Thermal shock

More on this next week …

- **Advantages:** scientific design, light spectrum, temps, water delivery
- **Disadvantages:** newer, less history, precise control required

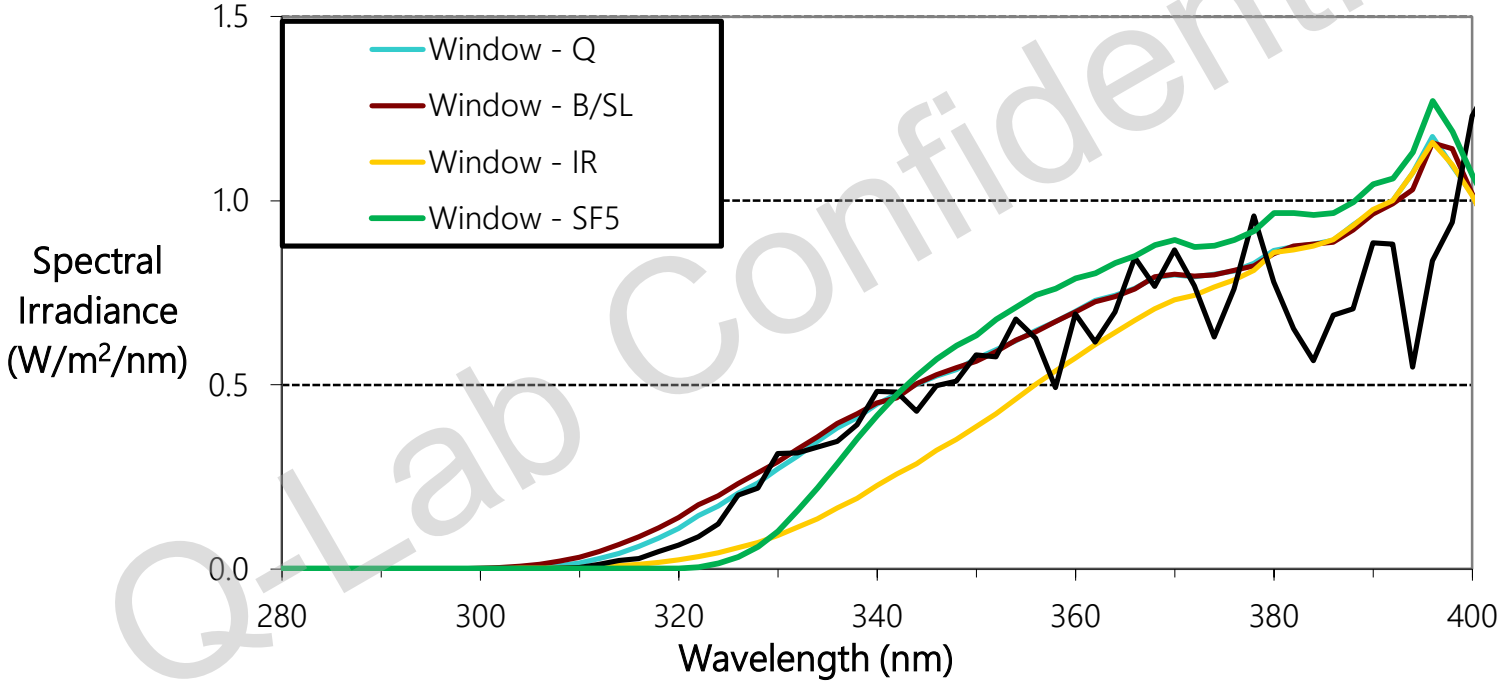
Automotive Weathering Testing

Exterior Test Summary

- Exterior automotive weathering tests intended to simulate outdoor sunlight, heat, and water experienced by autos
- Wide variety of test conditions
  - Selection depends on equipment, goals, time
  - Material type can influence choice as well

Automotive Weathering Testing

Interior Light Spectra: Which best simulates auto glass?

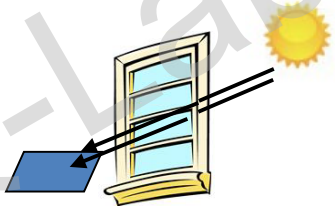
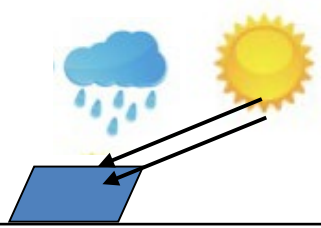
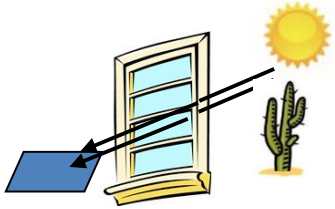
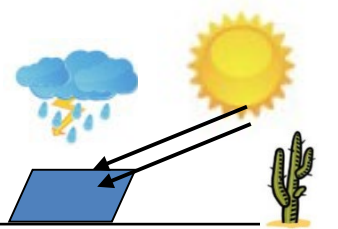


Products and Interior Test Standards

Product	Test type	Major test standards
Apparel and Design Fabrics	Lightfastness	• ISO 105:B02 • ISO 105:B04 (like B02 but with water) • AATCC TM 16 (Option 3) • Other derivatives like Marks & Spencer
Automotive and high-temp	Lightfastness	• ISO 105:B06 • VDA (DIN) 75202 • SAE J2412 • IUF 402 – Int'l Union of Leather Technologists and Chemists Societies
Outdoor and Industrial Textiles	Weathering	• AATCC TM 169 (xenon) • AATCC TM 186 (fluorescent UV) • ISO 105:B03 (outdoor)

ISO 105-B02, -B04, B06 & -B10

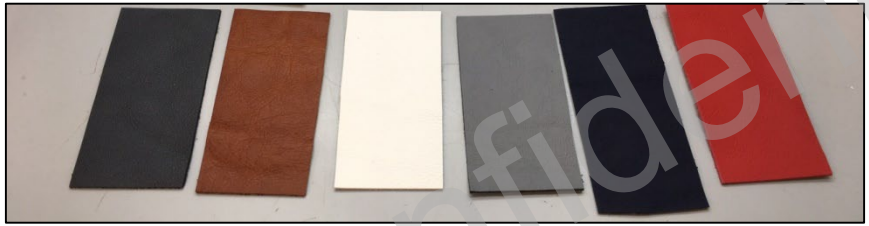
A variety of exterior and interior test protocols

Aspect	B02	B04	B06	B10
Environment	Interior	Exterior	Interior	Exterior
Irradiance (W/m² TUV)	42	42	45	60
Cut-on wavelength (nm)	315	300	310	290
UV light	Low	Medium	Low	High
IR light	Suppressed	Suppressed	High	High
Water cycle	Dry only	Cyclic dry/spray	Dry only	Cyclic dry/spray option
Graphic				

Interior Material Testing

Testing of Leather Specimens per SAE J2412

As-received



440 kJ

1015 kJ

Automotive Weathering Testing

Basic Interior Tests (ASTM)

ASTM INTERNATIONAL

ASTM G155

Cycle	Filter	Irradiance and Wavelength	Exposure Cycle	Black Panel Temperature (BPT) (°C)	Relative Humidity (RH) (%)	Chamber Air Temperature (CAT) (°C)
6	Window Glass	1.10 W/(m^2· nm) @ 420 nm	228 min light	63	35	*47*[A]
			60 min dark[D]	43	90	*43*[A]

Very popular test

- **Advantages:** history, general applicability
- **Disadvantages:** not scientifically designed, may lack correlation

Automotive Weathering Testing

Basic Interior Tests (ISO)

ISO 4892-3, 16474-3

Used around the world

Cycle No.	Exposure period	Lamp type	Irradiance	Black-panel temperature
Method B: Artificial accelerated weathering with UVA-351 lamps				
5	24 h dry (no moisture)	UVA-351 (type 1B)	0,76 W·m^{-2} × nm^{-1} at 340 nm	50 °C ± 3 °C

ISO 4892-2, 16474-2

Method B — Exposures using window glass filters						
Cycle No.	Exposure period	Irradiance		Black-standard temperature °C	Chamber temperature °C	Relative humidity %
		Broadband (300 nm to 400 nm) W/m^2	Narrowband (420 nm) W/(m^2·nm)			
2	Continuously dry	50 ± 2	1,10 ± 0,02	65 ± 3	38 ± 3	50 ± 10[c]
3	Continuously dry	50 ± 2	1,10 ± 0,02	100 ± 3	65 ± 3	20 ± 10

- **Advantages:** history, general applicability
- **Disadvantages:** not scientifically designed, may lack correlation

Automotive Weathering Testing

Popular Interior Test: SAE J2412

Controls	Dark Cycle		Light Cycle	
	Target	Tolerance	Target	Tolerance
Automatic Irradiance	None		Contractual Agreement (See Note 1)	± 0.02 Wm^2 nm^{-1}
Black Panel Temperature	38 °C	± 2.5 °C	89 °C	± 2.5 °C
Dry Bulb Temperature	38 °C	± 3 °C	62 °C	± 2 °C
Relative Humidity	95%	± 10%	50%	± 10%
Radiant Exposure	Not applicable		Contractual Agreement	
Cycle Duration	1 hour (See Note 2)	± 6 minutes	3.8 hours (See Note 2)	± 6 minutes

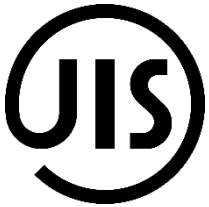
High T

Seems easy

- **Advantages:** history, general applicability, includes dark
- **Disadvantages:** UV optical filter totally and wildly inappropriate

Automotive Weathering Testing

High Irradiance Interior Tests



ASTM G155

Cycle	Filter	Irradiance and Wavelength	Exposure Cycle	Black Panel Temperature (BPT) (°C)	Relative Humidity (RH) (%)	Chamber Air Temperature (CAT) (°C)
10	Window Glass	162 W/m^2 @ 300 - 400 nm	Continuous Light	89	50	Uncontrolled

This is the interior "3 sun" test

- Advantages: *Speed!!!*
- Disadvantages: C o r r e l a t i o n

OEM Interior Test Standards

Standard	Name	Who
PV1303	Non-Metallic Materials: Exposure Test of Passenger Compartment Components	Volkswagen
GMW 14162	Colorfastness to Artificial Weathering	General Motors
FLTM BO 116-01	Exposure of Interior Trim Materials using a controlled irradiance water cooled xenon-arc	Ford
D47 1431	Materials and Passenger Compartment Parts Behaviour of the Appearance to Artificial Light at High and Medium Temperatures	Renault
DBL 5555	Finished Parts and Semi-Finished Products Made of Organic Polymer Materials General Conditions and Test Methods	Daimler

Automotive Weathering Testing

Interior Test Summary

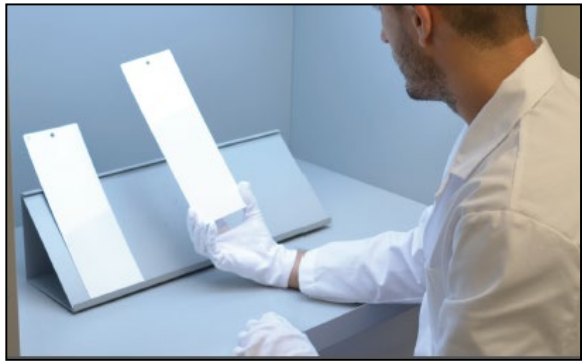
- Interior automotive weathering tests intended to simulate sunlight behind glass and trapped heat experienced by auto cabin components
- Wide variety of test conditions
  - Selection depends on equipment, goals, time
  - Material type can influence choice as well

Automotive Weathering Testing

Test Guidelines

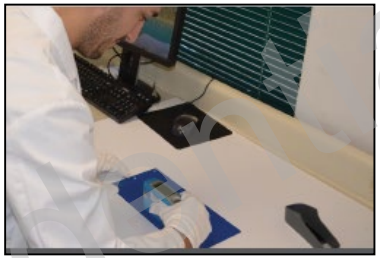
- Length of test depends on test conditions, failure mode, and durability of material
  - 2000-3000 hour tests are common for automotive coatings
  - Test to failure
- Critical to determine failure mode of interest
  - Gloss, color, tensile strength, adhesion

Evaluations



Visual

Mechanical



Color and gloss

Evaluation measurements performed to ASTM, ISO, other standards

Summary – Automotive Weathering Testing

- Automotive exterior and interior materials experience a wide range of physical and chemical degradation from sunlight, heat, and water in service environments
- Natural outdoor test methods like Black Box, Under-glass, and whole car can simulate automotive conditions
- Accelerated outdoor tests like AIM Box and natural solar concentrator provide enhanced testing outdoors
- Xenon arc and fluorescent UV accelerated test chambers can provide results in a shorter timeframe
- Wide variety of tests for interior and exterior materials to select from

Thank you for your attention!

Questions?

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