

# Essentials of Laboratory Weathering

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Q-Lab

[View Recorded Presentation](#)

# Q-Lab's 2023 Webinar Series

This is the penultimate webinar in our 2023 series.

Thanks to everyone who attended these sessions!

All the content can be accessed at: [q-lab.com/webinars](https://q-lab.com/webinars)

Title	Grouping
Outdoor Testing	Outdoor
Accelerated Outdoor Weathering Testing	
Optimizing your weathering program	
QUV Operator Training - with live content	Operator training
Q-SUN Operator Training - with live content	
Q-FOG Operator Training - with live content	
How to Run ASTM B117	Practical / Educational
Evaluations in weathering testing	
MAPS Ask Me Anything	
Essentials of Lab Weathering	Fundamentals
Modern Corrosion	

# Administrative Notes

You'll receive a follow-up email from [info@email.q-lab.com](mailto:info@email.q-lab.com) with links to take a survey and download the presentation content

Use the Q&A feature in Zoom to ask us questions today!



We make testing simple.



**Thank you for attending our webinar!**

We hope you found our webinar on *Essentials of Laboratory Weathering* to be helpful and insightful. The link below will give you access to the slides and recorded webinar.

# What We Will Talk About

- Basics of Weathering
- Why Perform Laboratory Weathering?
- Laboratory Weathering Testing
  - Xenon
  - Fluorescent UV
- Elements of an Effective Testing Program

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# 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*

# Sunlight

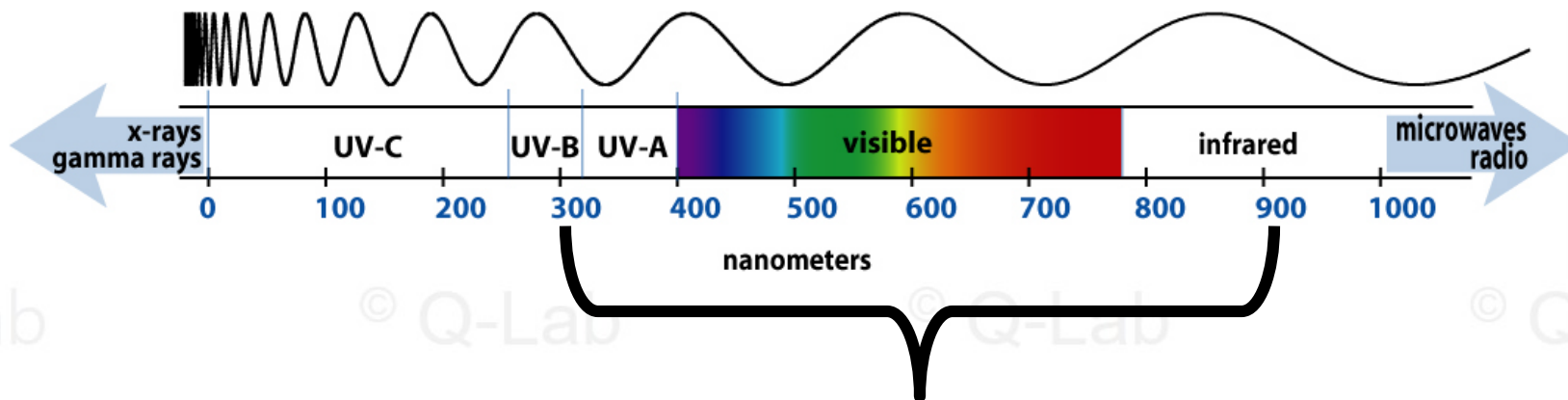




# Sunlight

- A form of energy
- Electromagnetic radiation
- Usually described in terms of irradiance & wavelength ( $\lambda$ )

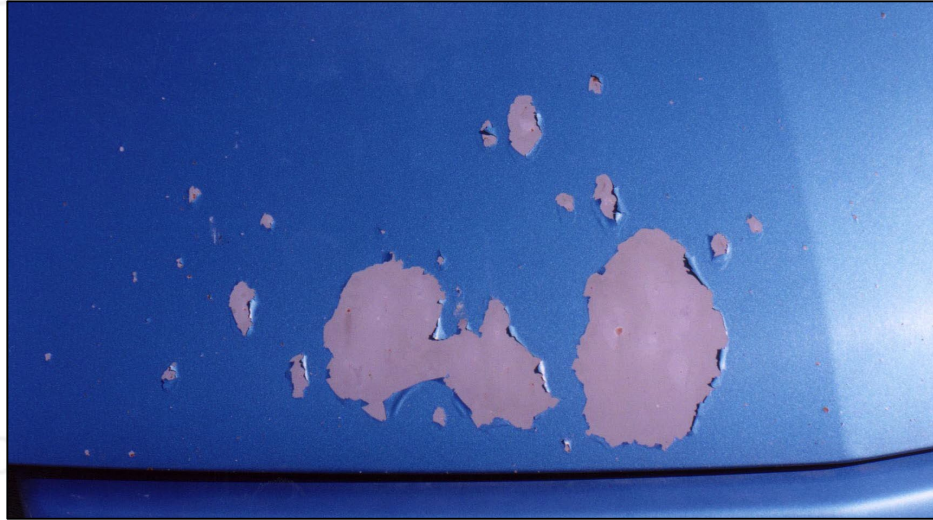
# Electromagnetic Spectrum



## Sunlight

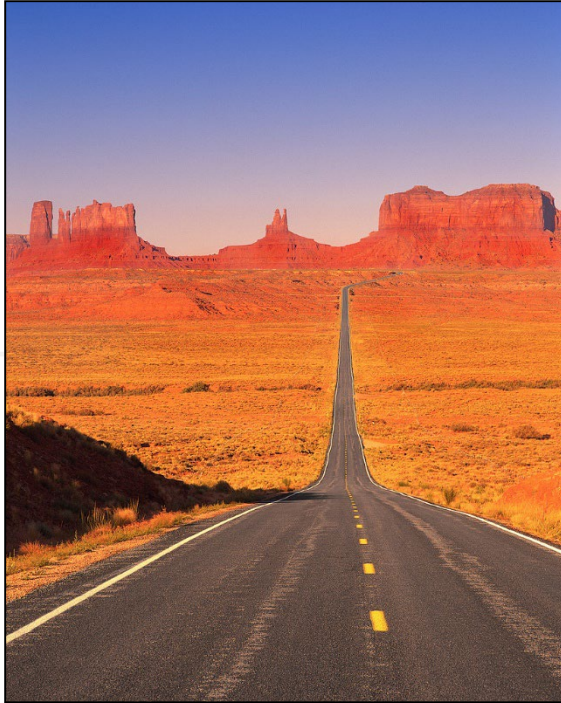
UV	295-400 nm	~7%
Visible	400-800 nm	~55%
IR	800-3000 nm	~38%

**Even though it is only 7% of sunlight's total radiant energy...**



UV causes virtually all polymer degradation!

# Irradiance



**Irradiance**<sup>1</sup> is the rate at which light energy falls on a surface, per unit area  
[W/m<sup>2</sup>] or [J/s·m<sup>2</sup>]

**Spectral irradiance**<sup>2</sup> is the irradiance of a surface per unit wavelength  
[W/m<sup>2</sup>/nm]

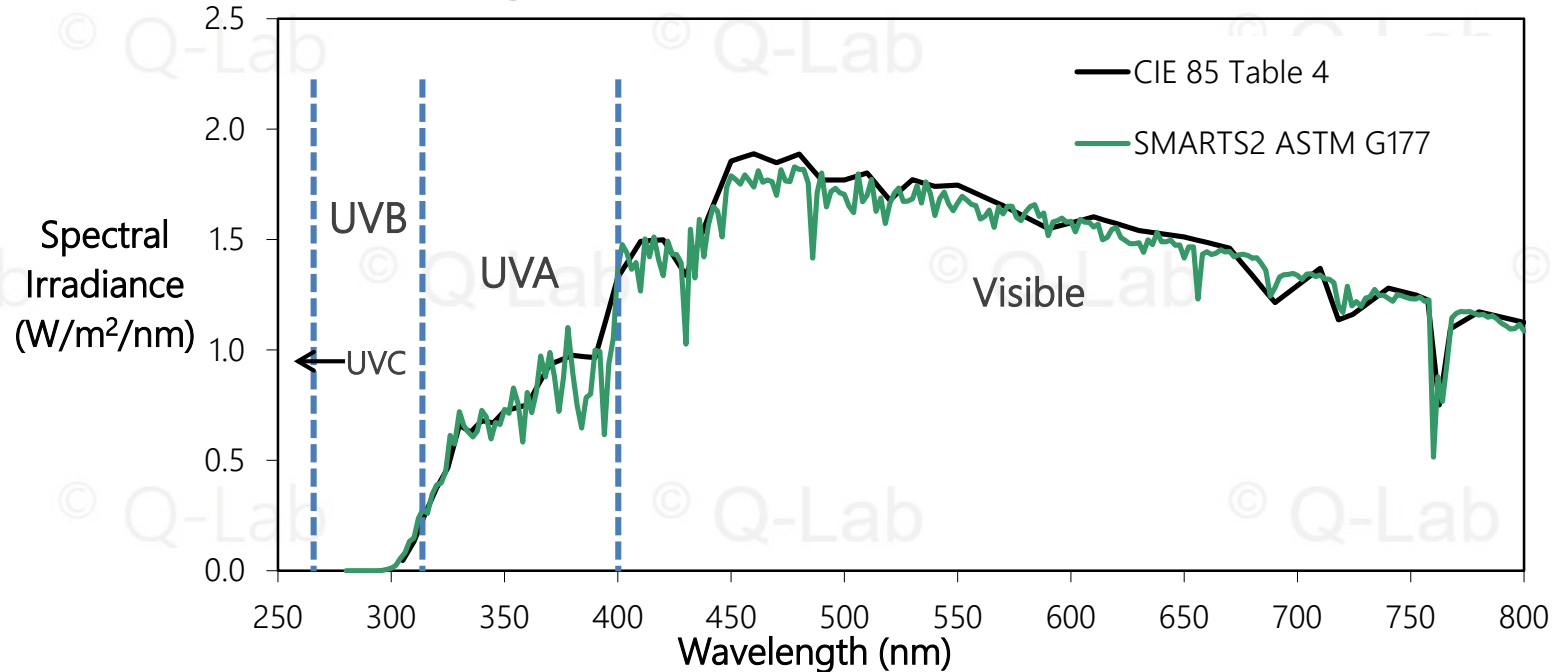
**Radiant exposure**<sup>1</sup> (or radiant dosage) is irradiance over a period of time  
[J/m<sup>2</sup>] or [W·s/m<sup>2</sup>]

*1 ASTM G113 – Terminology*

*2 ISO 9288 – Physical quantities and Definitions*

# Spectral Power Distribution (SPD)

## Noon Summer Sunlight



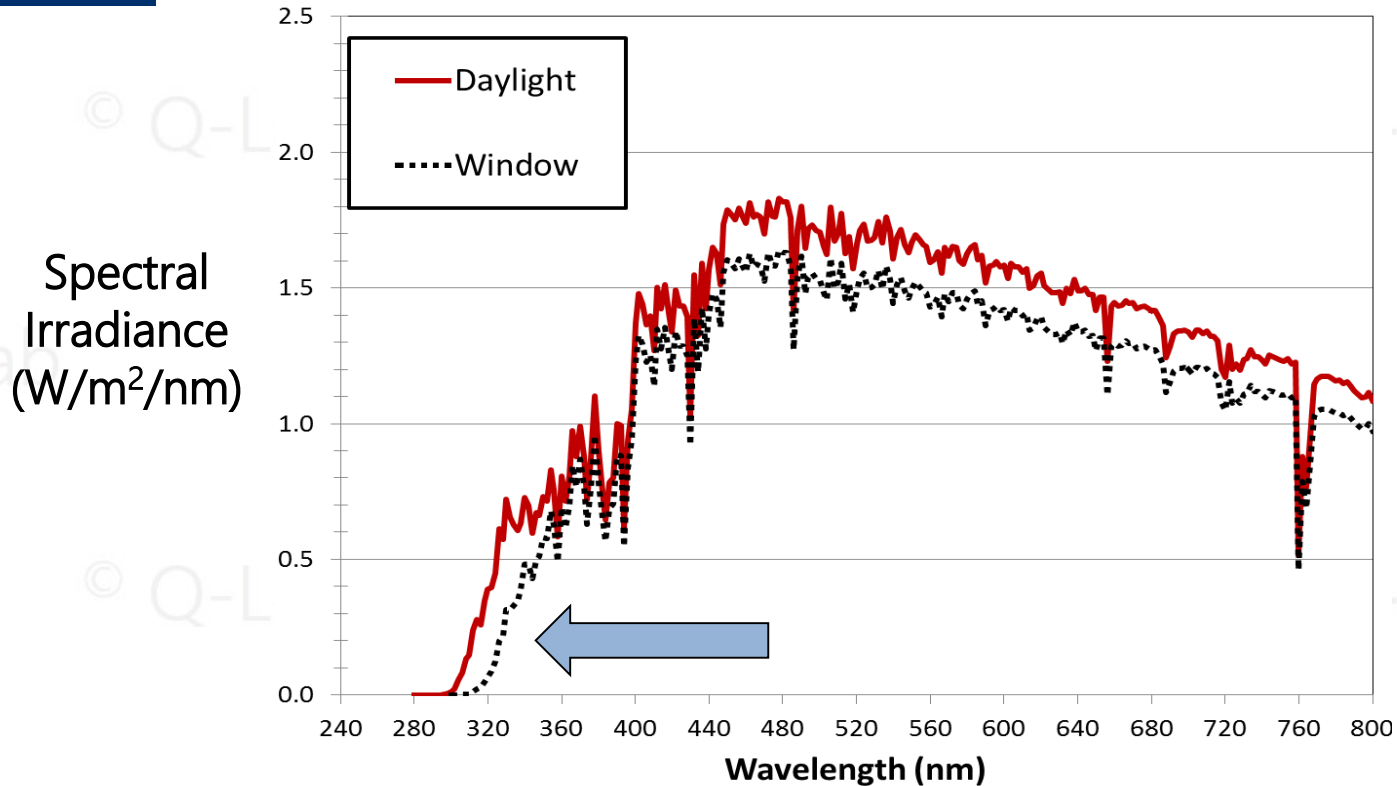
SPD: The absolute or relative radiant power emitted by a source, or incident upon a receiver as a function of wavelength. (ASTM G113)

# Spectrum Modifiers

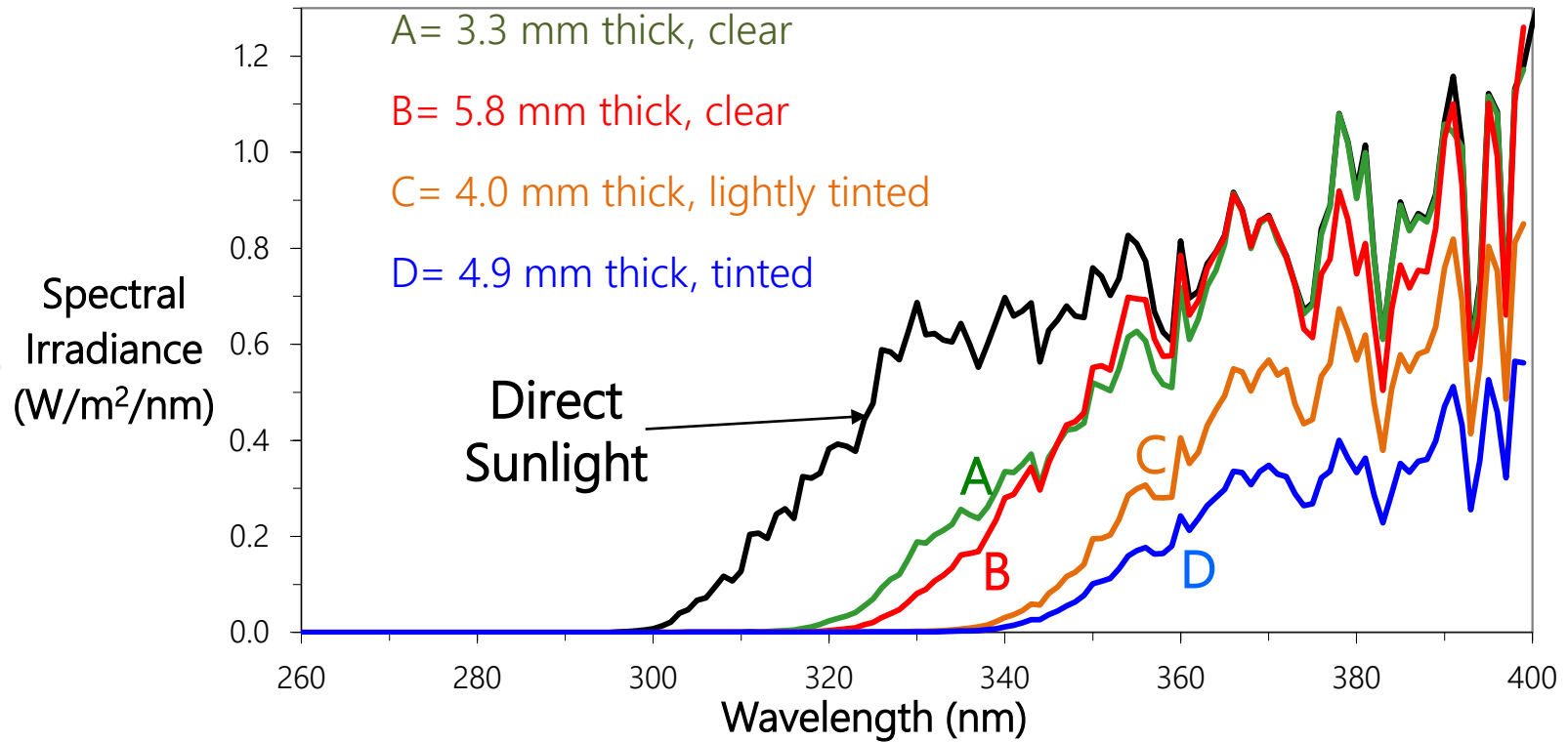


- Sun angle
  - Time of Year (e.g. summer)
  - Time of Day (e.g. noon)
  - Latitude
- Altitude

# Sunlight Through Window Glass

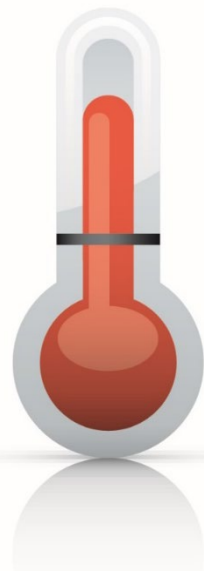


# Sunlight Through Automobile Glass





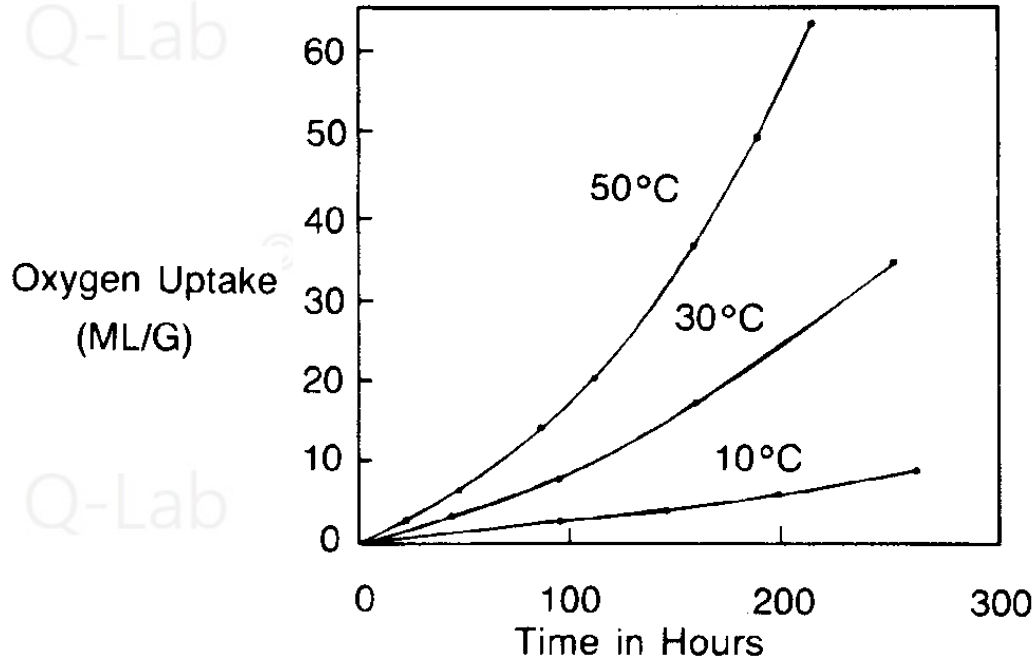
# Heat



# Heat Effects

- Elevated specimen temperature
- Dimensional change
- Evaporation
- Thermal aging
- Thermal cycling

# Effect of Temperature: Oxidation Rate of Polyethylene



*\*Time In Hours Exposed to UV lamps*

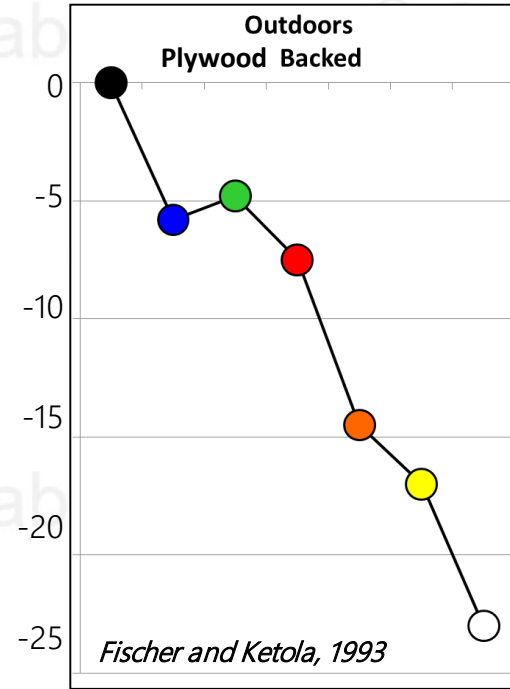
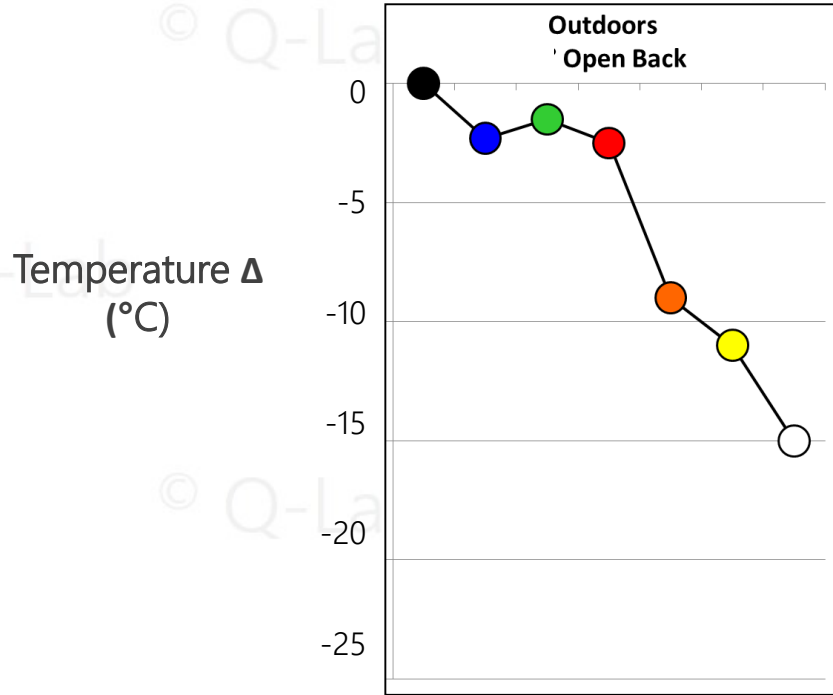
# Thermal Cycling in Florida

- 75°C to 25°C in 2 minutes
- Causes physical stress
- Affects coatings on plastics and assemblies



# Temperature and Color

## Darker Colors Have Higher Temperatures!



# Heat behind Window Glass



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

# Water



# Major Effects of Water

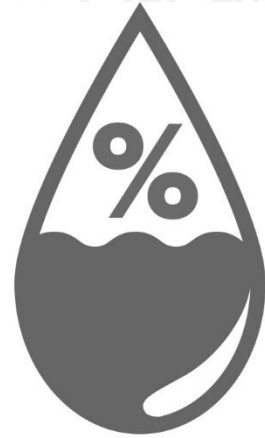
- Chemical Reactions
  - Reactions in solution
  - Facilitates reaction via increase in oxygen transport
- Physical Effects
  - Erosion
  - Absorption/freeze-thaw
  - Thermal shock
  - Impact (material loss)





# Humidity

- Measure of amount of water in air
- Can lead to physical stress
- Humidity affects products both indoors and outdoors
- Often expressed as Relative Humidity (RH), where 100% is the most water that air of a given temperature can hold



# Rainfall

- Surface effects
  - Washing away surface layers
  - Chalking
  - Dirt removal
- Thermal shock



# Dew

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- Moisture from the atmosphere that forms in the form of small drops upon any cool surface
- High O<sub>2</sub> content
- Long dwell time



# Dew, not Rain, Is the Source of Most Outdoor Wetness!



Q-Lab © Q-Lab © Q-Lab © Q-Lab

# Dew Is Not Simulated in Many Accelerated Lab Weathering Tests!



# Don't Underestimate the Effect of Moisture!

- Changes the **rate** of degradation
- Changes **mode** of degradation
- Difficult to accelerate

# Summary: Forces of Weathering

- Sunlight
  - UV light causes virtually all polymer degradation
  - Small changes in material formulation and/or spectrum can have large effects on material degradation
- Heat (Temperature)
  - Sunlight + Heat = increased rate of degradation
  - A material's color strongly affects how hot it will get in sunlight
- Water (Moisture)
  - Sunlight + Heat + Water = Weathering
  - Dew, not Rainfall, is the source of most outdoor wetness
  - Products outdoors are wet much longer than you think

*Weathering includes synergistic effects between these factors!*

# What We Will Talk About

- Basics of Weathering
- **Why Perform Laboratory Weathering?**
- Laboratory Weathering Testing
  - Xenon
  - Fluorescent UV
- Elements of an Effective Testing Program



# Why Test?

- Meet specifications
- Avoid catastrophes
- Enhance your reputation
- Verify supplier claims
- Improve product durability
- Save on material costs
- Expand existing product lines
- Enter new markets
- Outrun the competition
- Stay ahead of regulations

# Laboratory Testing is a Tool for Directional Decision-Making

Laboratory Accelerated tests can help you:

- Make decisions better and/or faster.
- Reduce risk of making bad decisions
- Reduce risk of making decisions too slowly

# What Kind of Test Should I Run?

Accelerated Test Type	Result	Test Time	Results compared to
Quality Control	Pass / fail	<ul style="list-style-type: none"><li>• Defined</li><li>• Short</li></ul>	Material specification

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Correlative	Rank-ordered data	<ul style="list-style-type: none"><li>• Open-ended</li><li>• Medium</li></ul>	Natural exposure (Benchmark site)

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Predictive	Service life Acceleration factor	<ul style="list-style-type: none"><li>• Open-ended</li><li>• Long</li></ul>	Natural exposure (Service environment)

# What is Natural Weathering?

Outdoor exposure of materials to unconcentrated sunlight, the purpose of which is to assess the effects of environmental factors on various functional and decorative parameters of interest.

Global benchmark weathering sites:

- South Florida (Subtropical)
- Arizona (Dry Desert)
- Midwest (Northern Industrial)

# Why Is Natural Weathering Important?

- Natural weathering is more complex than artificial (laboratory) weathering
- Accelerated laboratory tests are not always realistic
- Laboratory test accuracy should always be verified by outdoor tests
- Ongoing outdoor weathering tests build a library of highly valuable data, at low cost

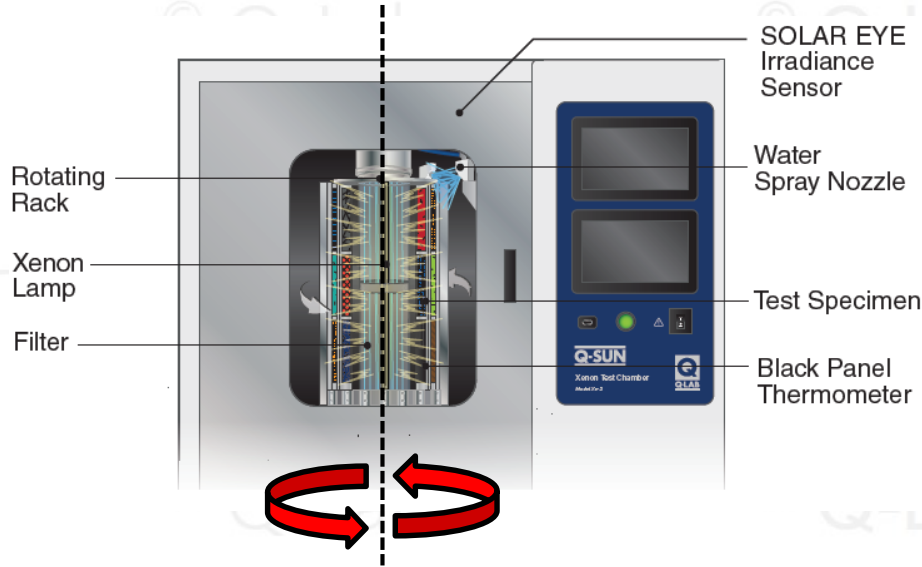


# What We Will Talk About

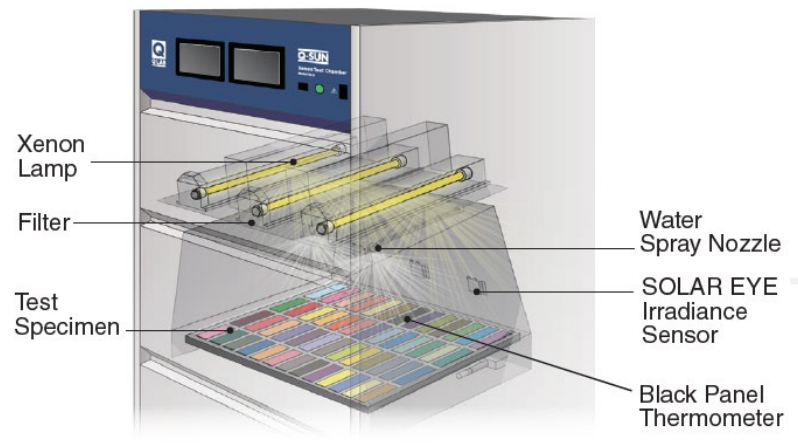
- Basics of Weathering
- Why Perform Laboratory Weathering?
- **Laboratory Weathering Testing**
  - Xenon
  - Fluorescent UV
- Elements of an Effective Testing Program

# Xenon Arc Laboratory Weathering

# Xenon Arc Test Chamber



Rotating Rack



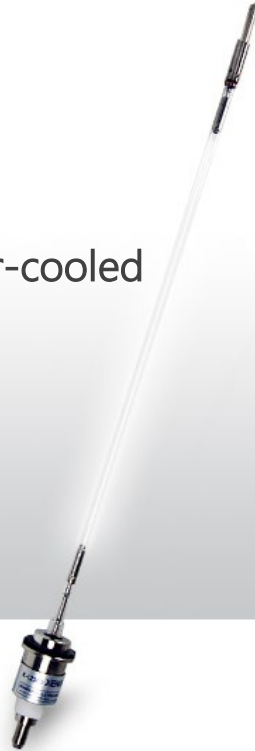
Flat Array

# Xenon Arc Lamps

Air-cooled



Water-cooled



Water-cooled  
Assembly

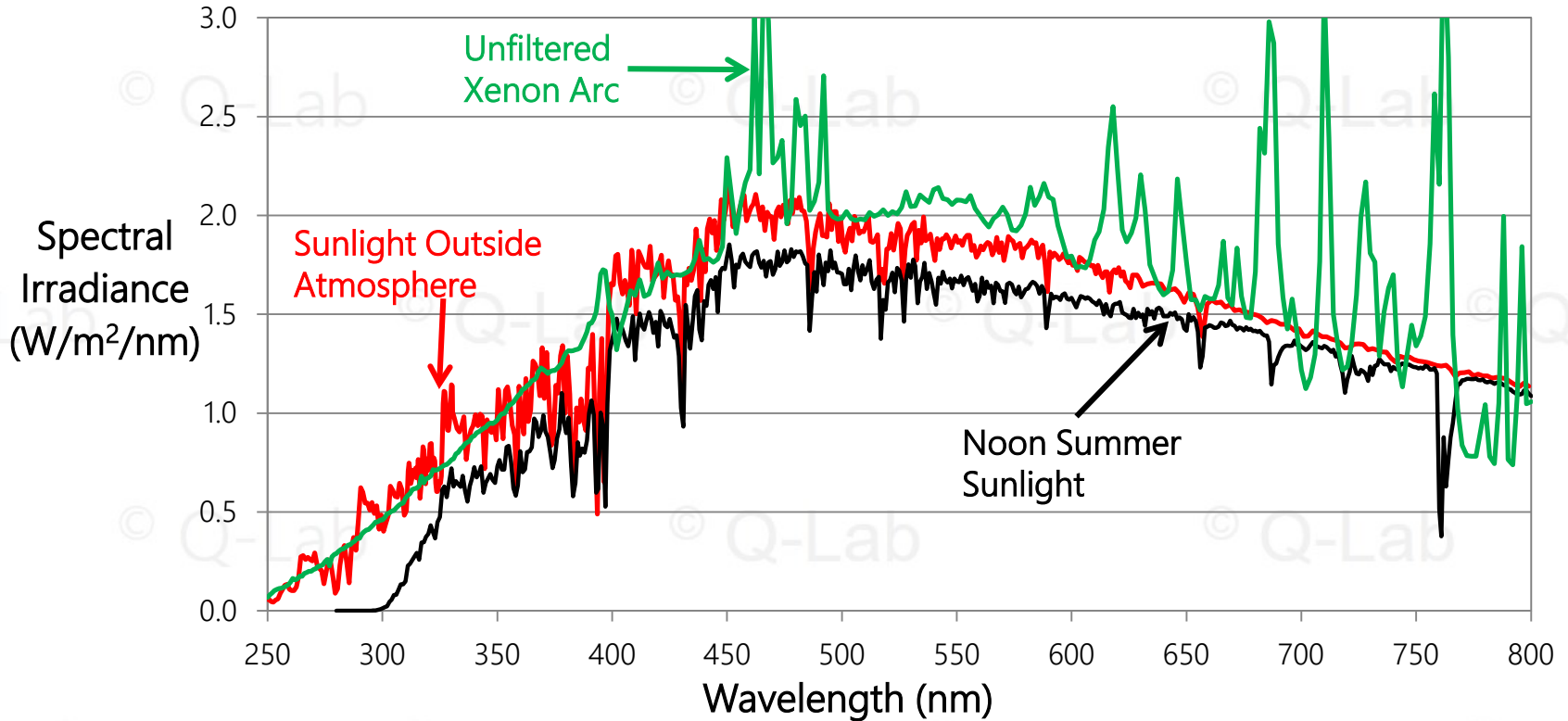


# Xenon Arc Spectra

## Major Influencing Factors

- Optical filters
- Irradiance level (intensity)
- Wavelength at which irradiance is controlled (“control point”)
- Lamp aging

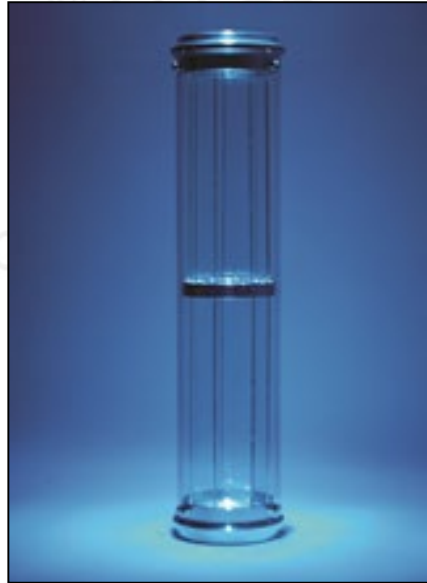
# Unfiltered Xenon Arc vs. Sunlight



# Overview of Filters

- Daylight
- Window
- Extended UV

Rotating drum "lantern"

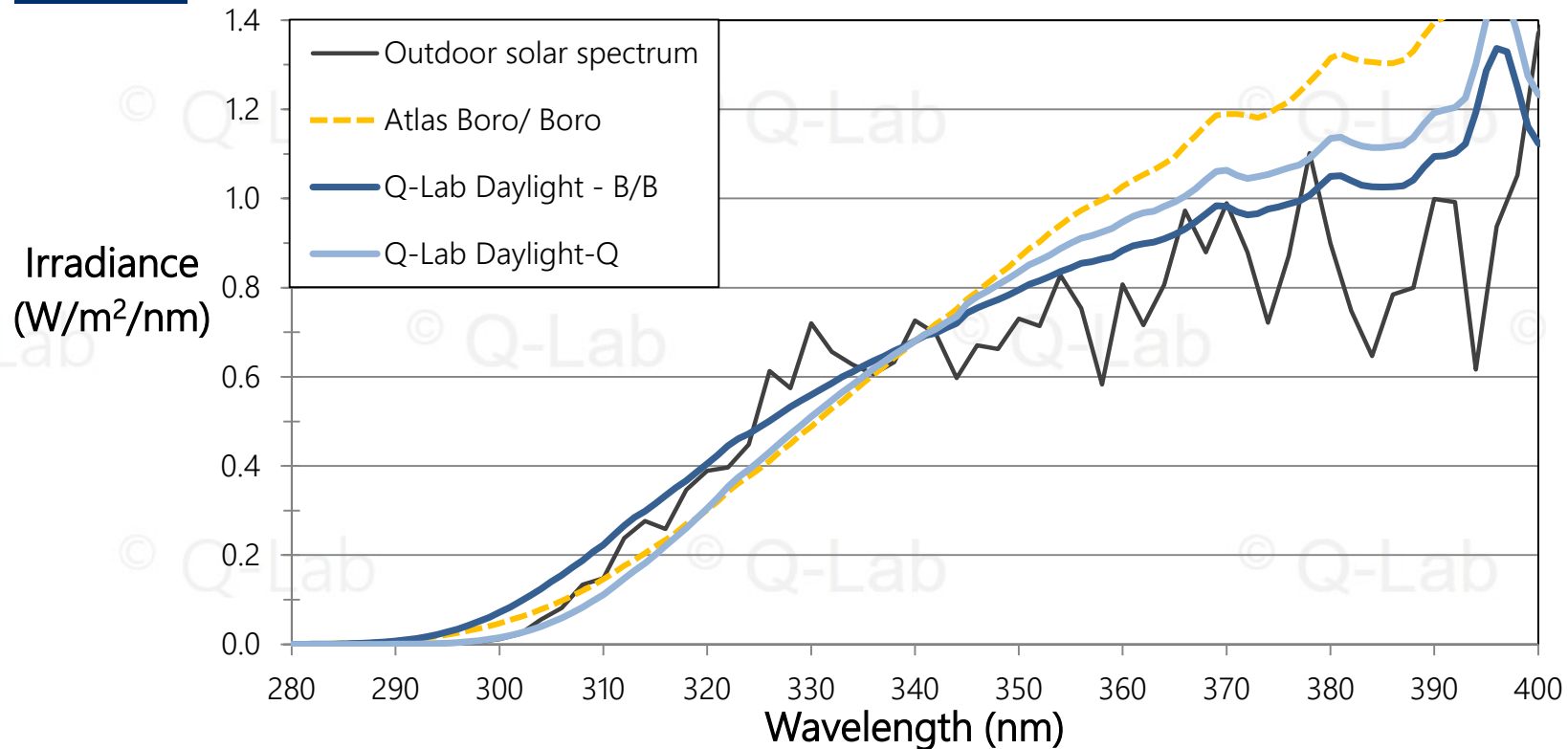


Flat array filter



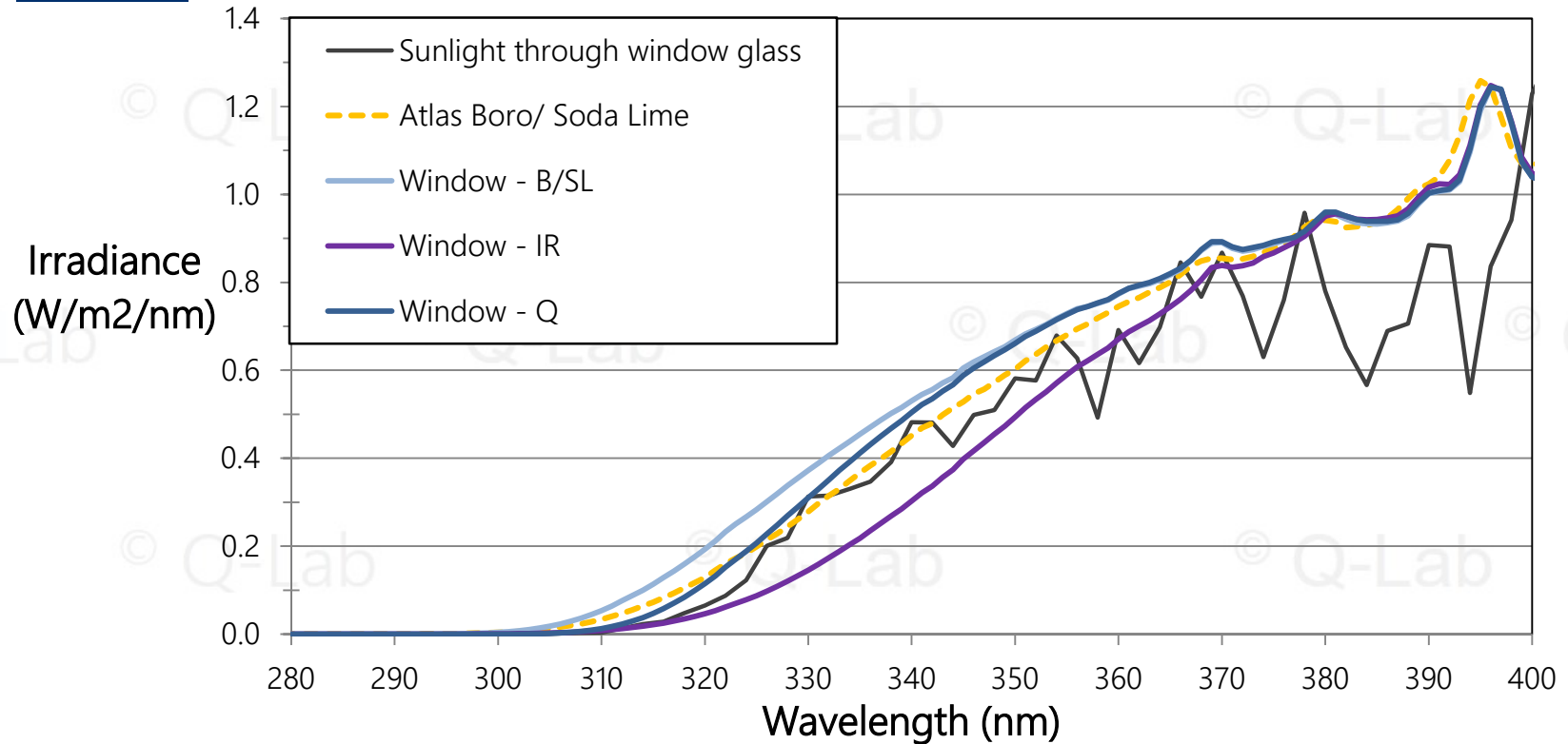
*\*Other specialized filters used occasionally*

# Daylight Filter Comparison

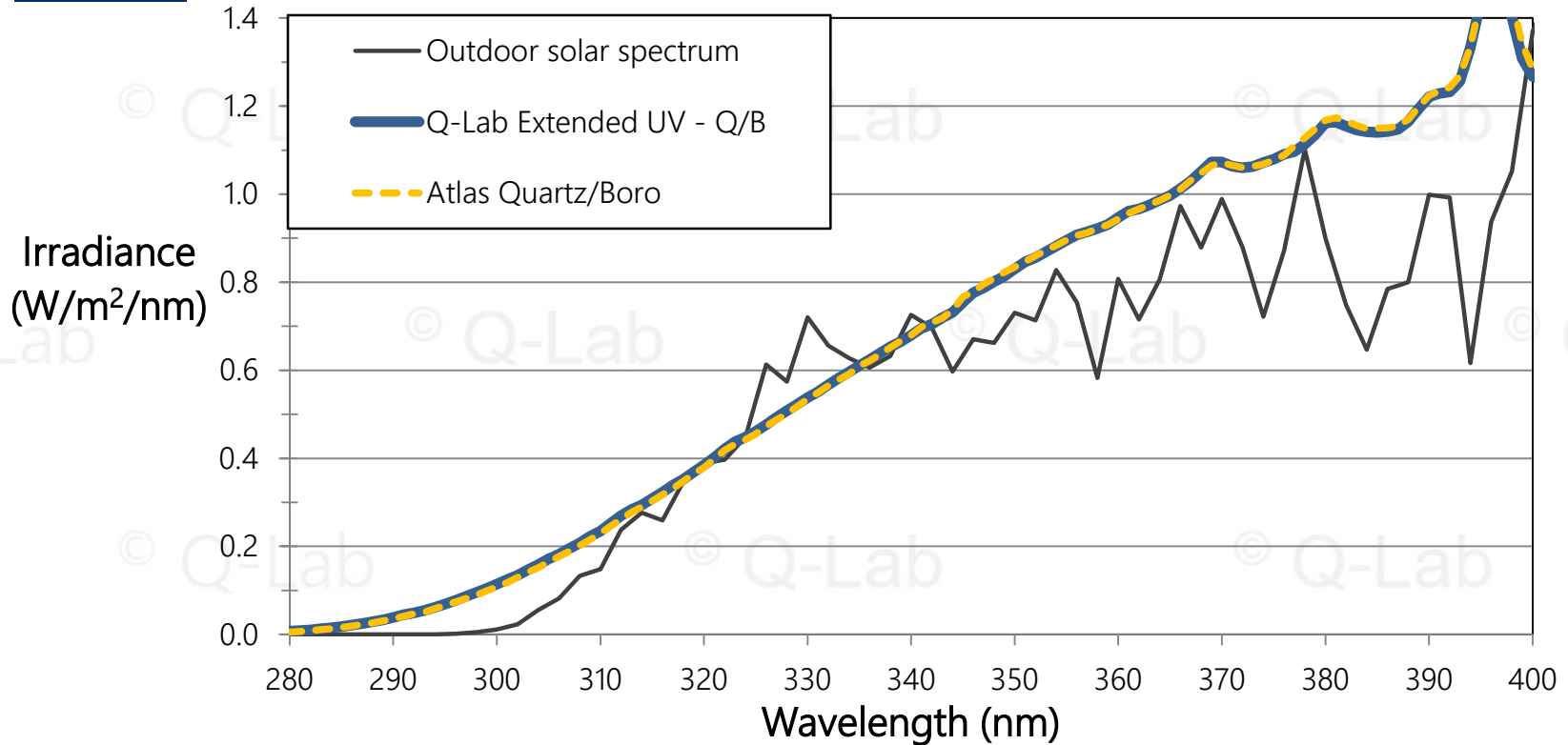




# Window Filter Comparison



# Extended UV Filter Comparison



# Optical Filter Aging

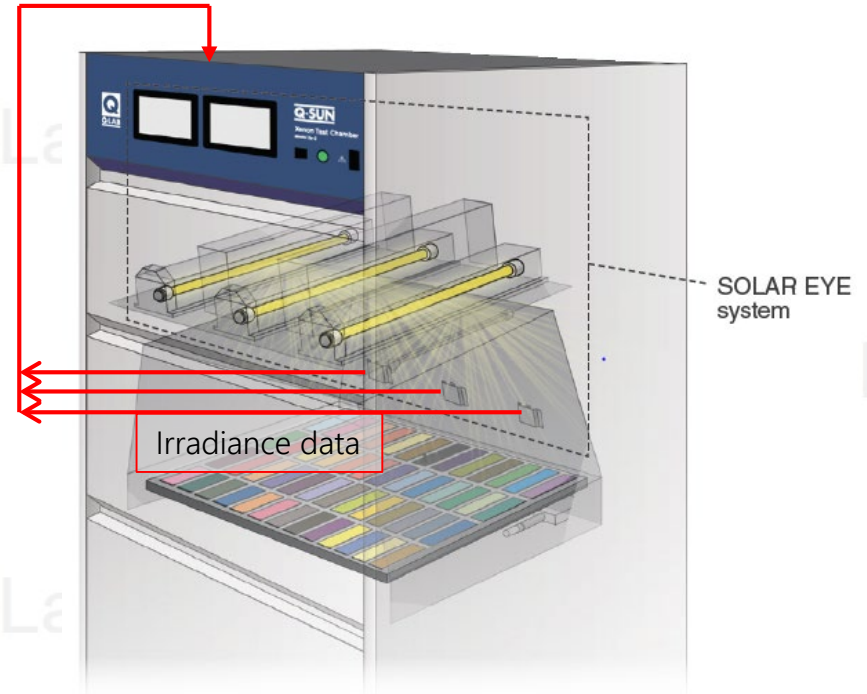
## Water-Cooled vs Air-Cooled

- Filters for water-cooled lamp systems need to be replaced every 400-2000 hours
  - Contaminants, even in ultra-pure de-ionized water, reduce filter transmittance over time
- Almost all filters for air-cooled lamp systems do not age or need to be replaced

# Q-SUN SOLAR EYE™

## Irradiance Control

- Feedback Loop Control
  - Xenon-arc lamp
  - Light sensor
  - Control module
- Wavelength at which irradiance is controlled is referred to as Control Point



# Irradiance Control Point Options

- Narrow Band
  - 340 nm
  - 420 nm
- Wide Band
  - Total UV TUV (300-400 nm)
  - Global (300-800 nm) – not recommended
    - Shorter wavelengths cause more photodegradation
    - Fails to account for xenon lamp aging

# Why Is Choice of Control Point Important?

- Xenon Arc lamps age with use
- Spectral shift limits useful lamp life
- Controlling irradiance in **wavelength region of interest** maximizes repeatability and reproducibility

# 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	Construction	ASTM Designation	ISO Designation
 A photograph of an uninsulated black panel temperature sensor. It consists of a black rectangular panel with a black handle and a blue sensor probe with a silver tip. A blue pen with the Q-Lab logo and 'q-lab.com' is placed next to it for scale.	Black painted stainless steel	Uninsulated Black Panel	Black Panel
 A photograph of an insulated black panel temperature sensor. It features a black rectangular panel mounted on a white base. A blue sensor probe with a silver tip is attached to the top. A blue pen with the Q-Lab logo and 'q-lab.com' is placed next to it for scale.	Black painted stainless steel mounted on 0.6 cm white PVDF	Insulated Black Panel	Black Standard

\* White Panel versions of the above are available but far less commonly used



**To maximize acceleration,  
use maximum service temperature**

To minimize error, *DO NOT* exceed  
maximum service temperature

# Chamber Air Temperature Control

- Required by certain test methods
- Necessary for control of relative humidity (RH)
- Sensor must be shielded from light
- BP temp always hotter than chamber air temp from absorbing radiant heat

# Relative Humidity Control

- Required by many test methods
  - Textiles
  - Automotive
- Many xenon testers can generate and control relative humidity
  - Boiler-type system
  - Nebulizer system
- 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

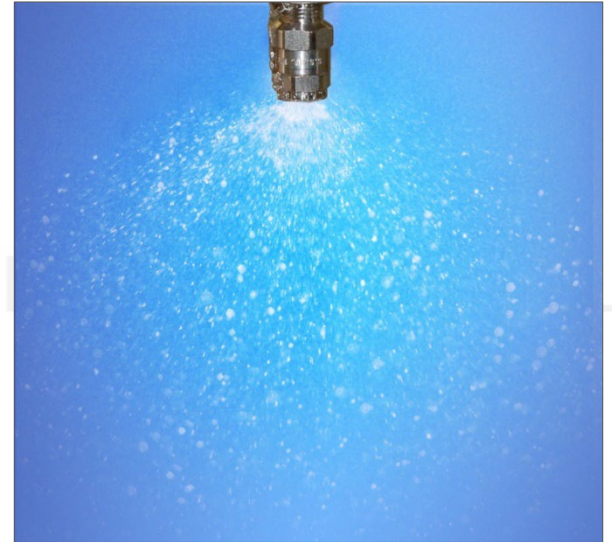
- Result of a failed experiment intended to generate condensation; persists in some standards

## Dual spray

- For delivering a 2nd solution, e.g. acid rain, soap

## Immersion (Ponding)

- Alternative to front spray called out in some standards



# Xenon Arc Summary

- Best simulation of full-spectrum sunlight
- Lamps experience aging (fulcrum effect)
- Temperature effects
- Water spray and RH control
- Additional cost, maintenance, and complexity compared to fluorescent UV testers

# Q-SUN Xenon Arc Testers

Xe-1



Xe-2

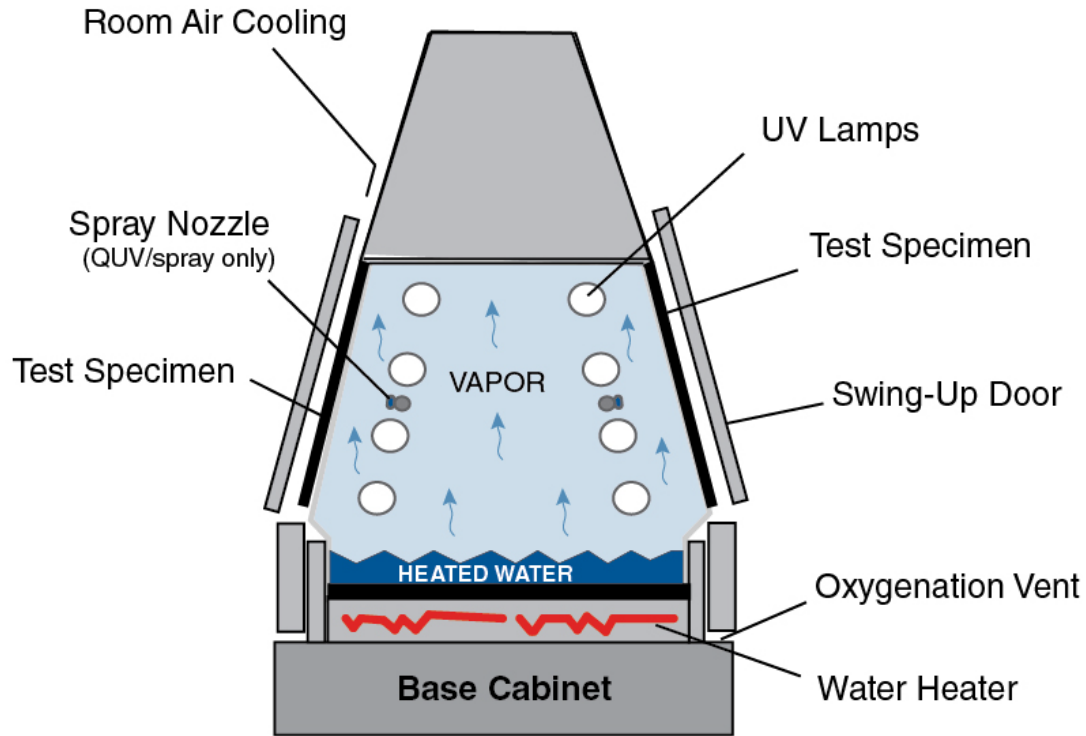


Xe-3



# Fluorescent UV Laboratory Weathering

# Fluorescent UV Schematic





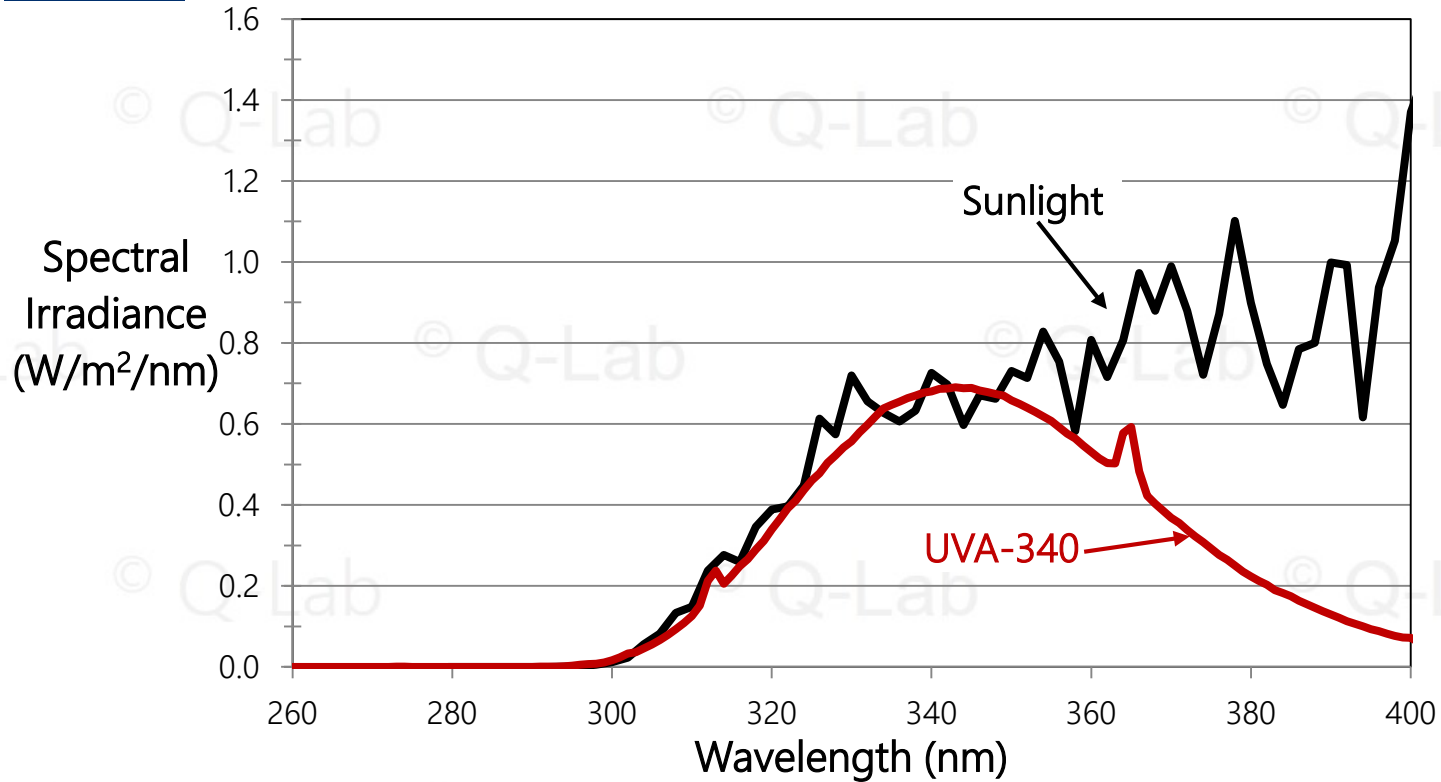
# Fluorescent UV Lamps



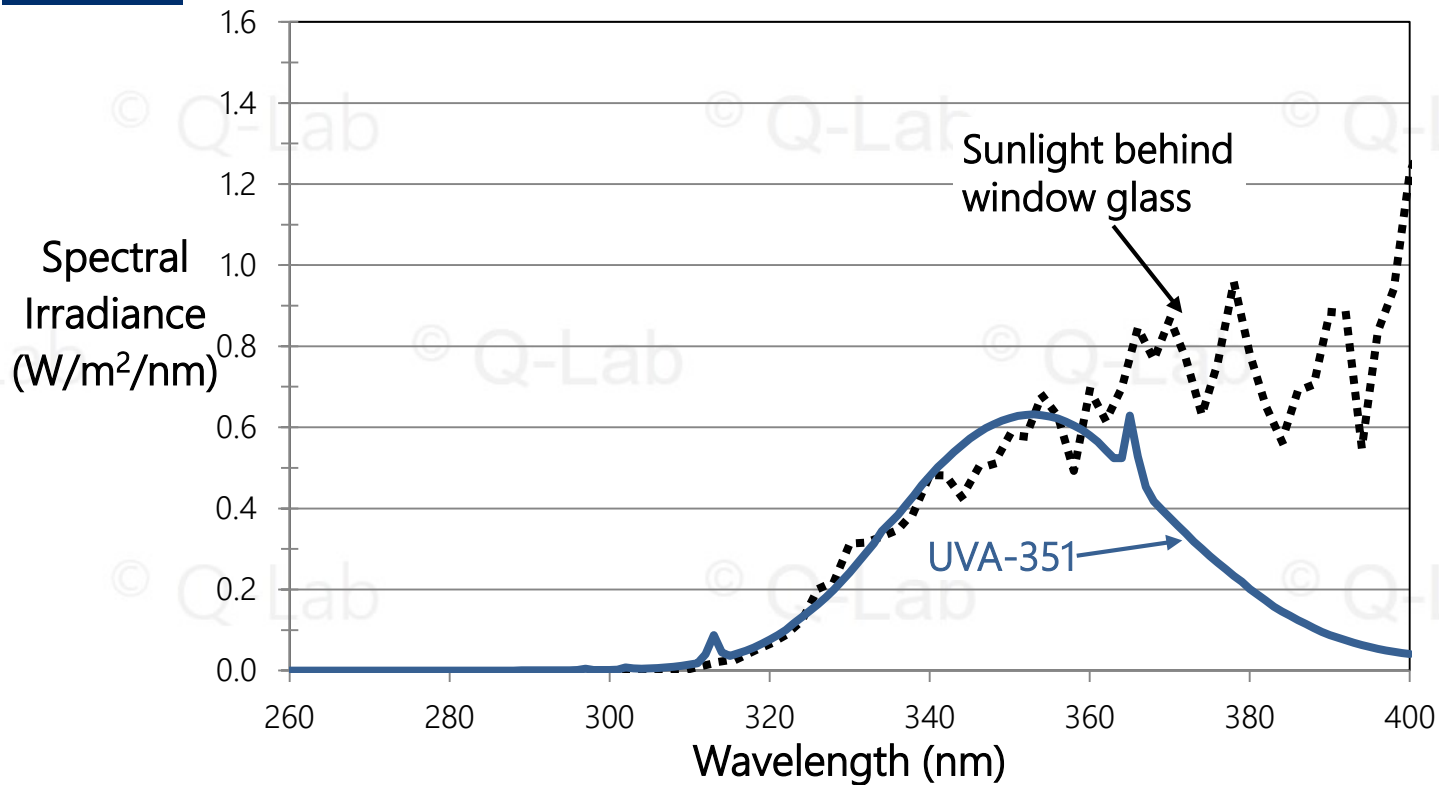
# QUV Lamp Summary

- UVA-340 (Daylight UV)
- UVA-351 (Window UV)
- UVB-313EL/FS-40 (Extended UV)
- UVC-254 (UVGI)
- Cool White (Indoor, office)

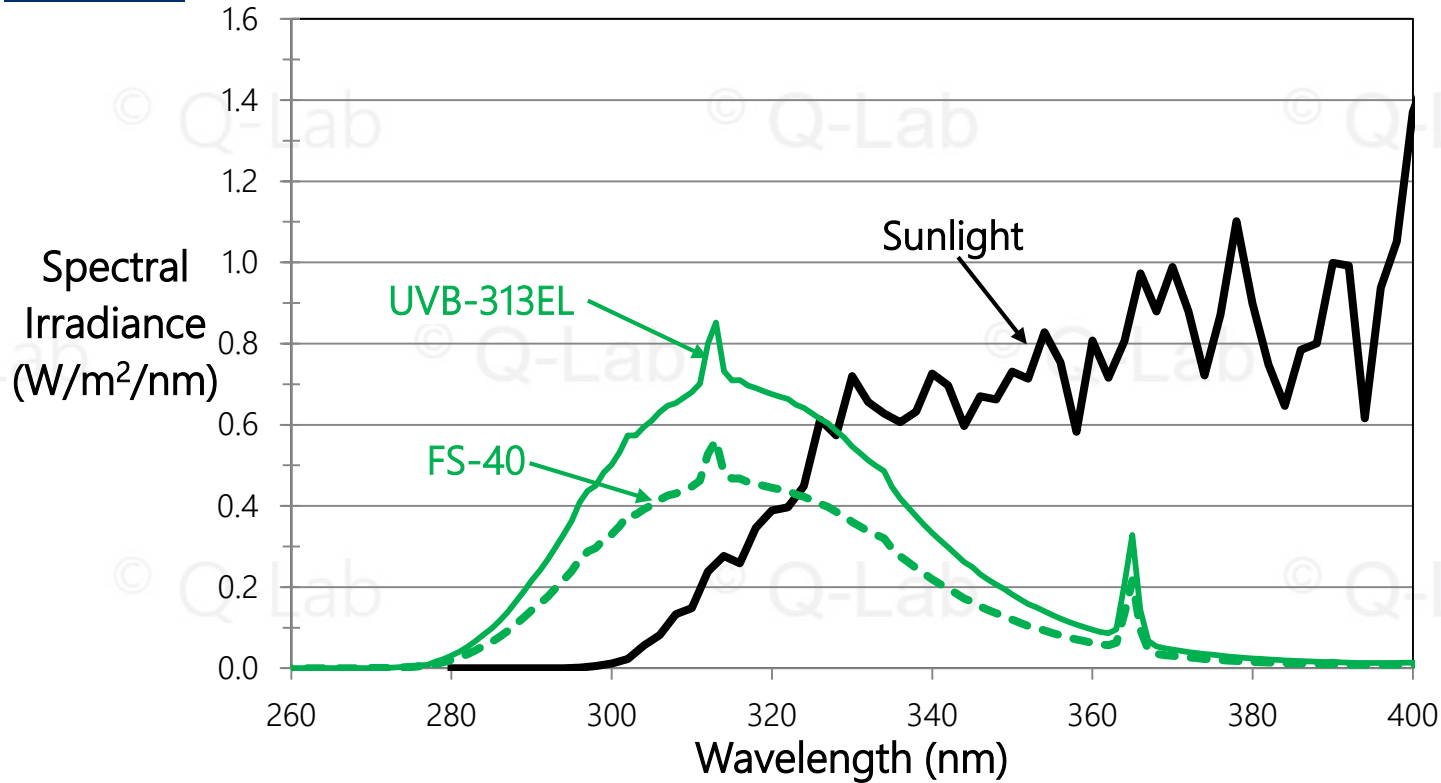
# UVA-340 Lamps



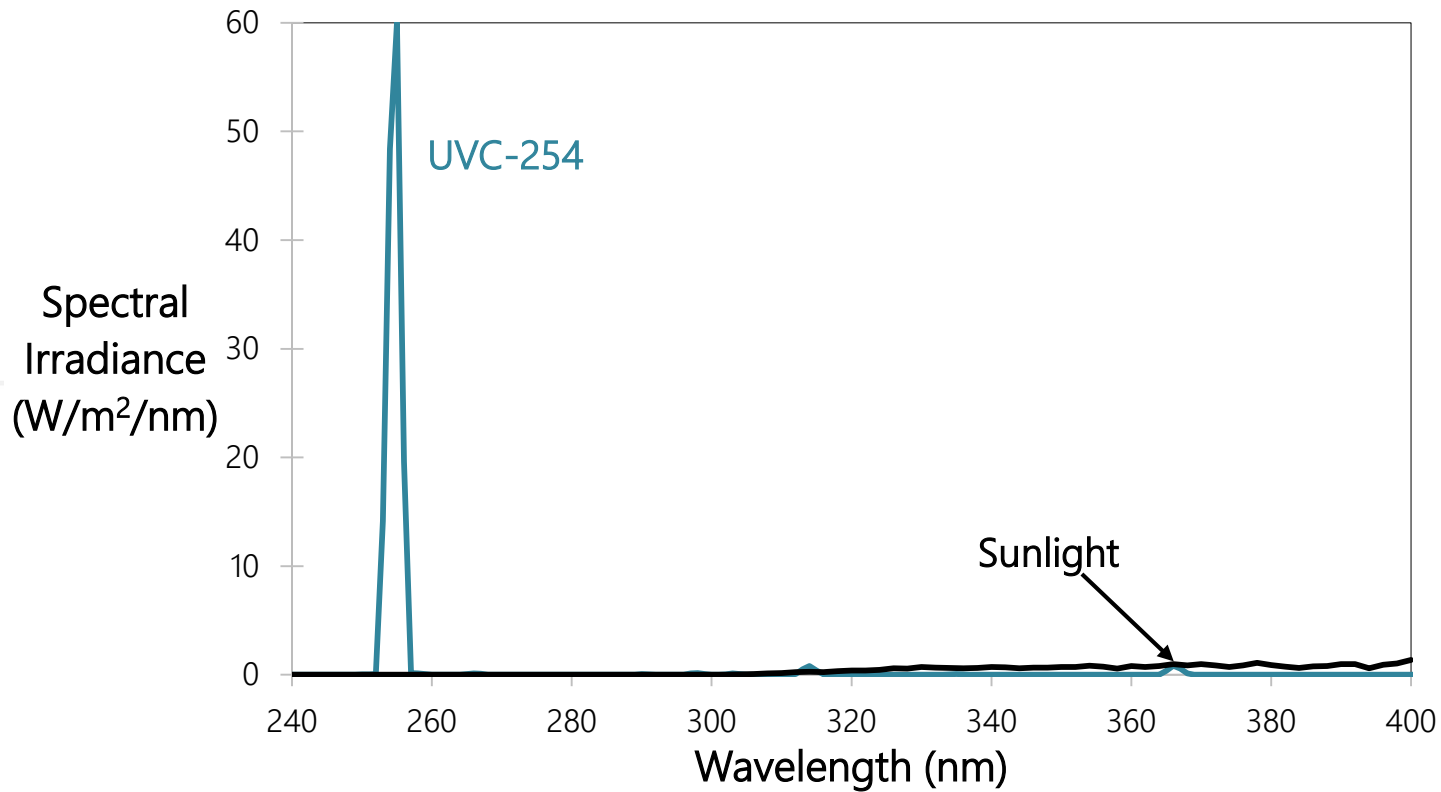
# UVA-351 Lamps



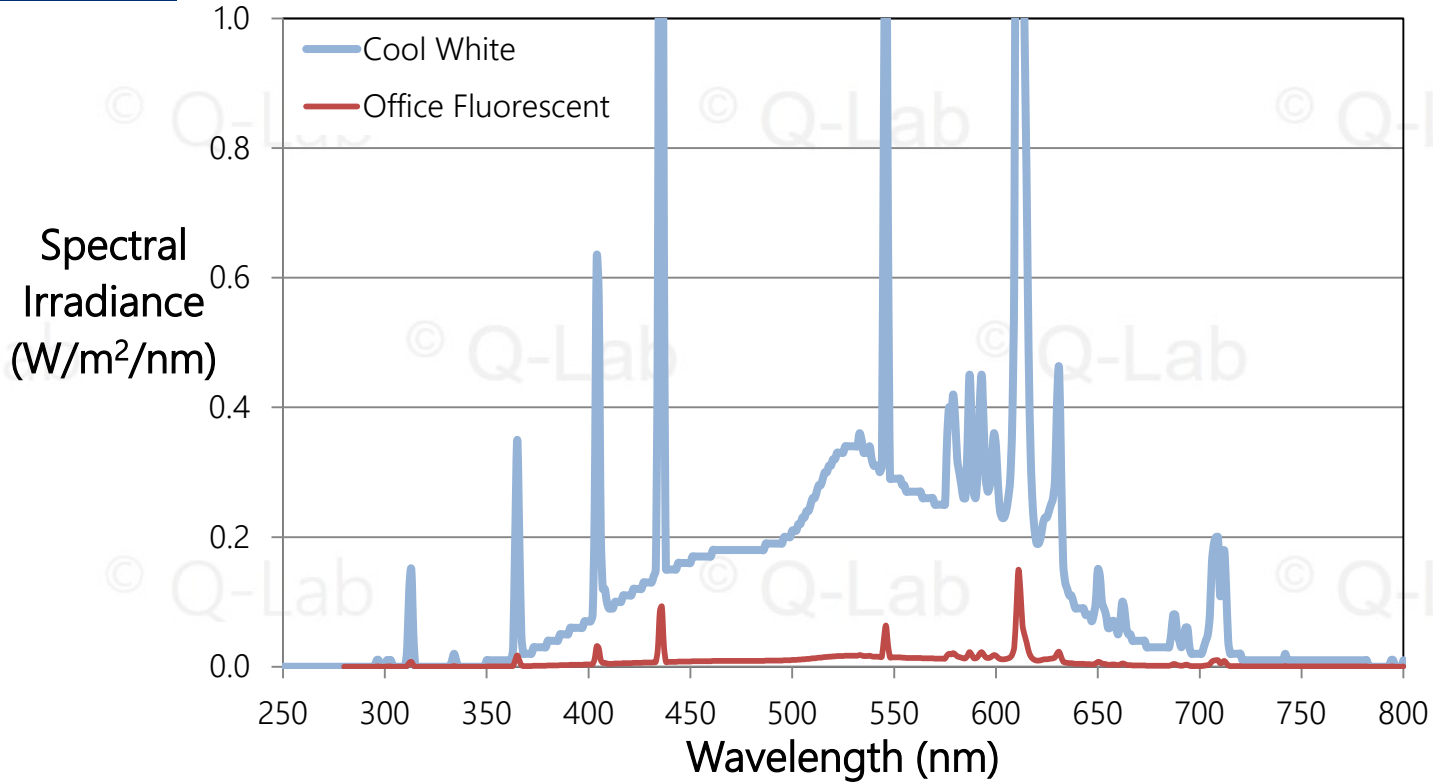
# UVB Lamps



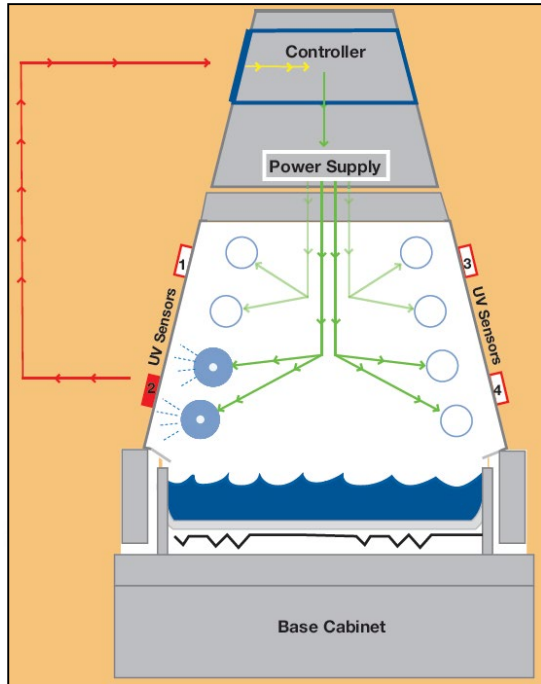
# UVC Lamps



# Cool White Lamps



# QUV SOLAR EYE™ Irradiance Control



## Feedback Loop Control

- Fluorescent UV lamp
- Light sensor
- Control module

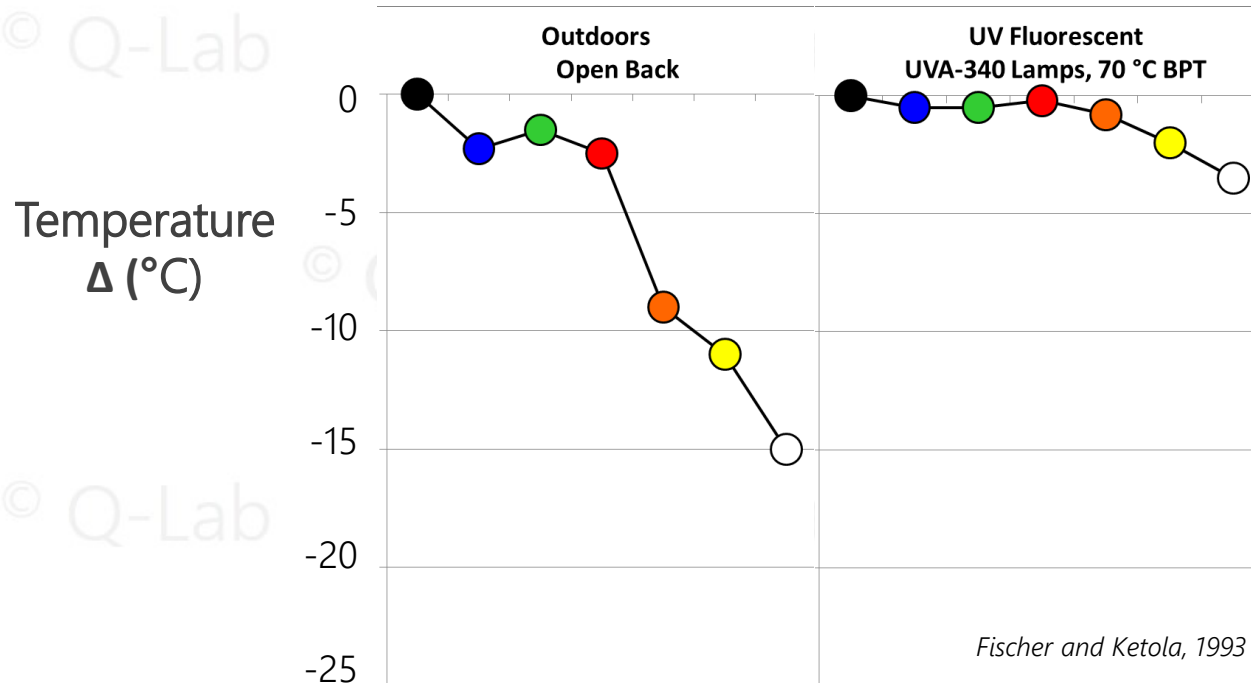


# Fluorescent Lamp Advantages

- Fast Results
- Simplified irradiance control
- Very stable spectrum – no aging
- Low maintenance
  - Simple calibration
- Low price and operating cost
- Simple and easy to maintain

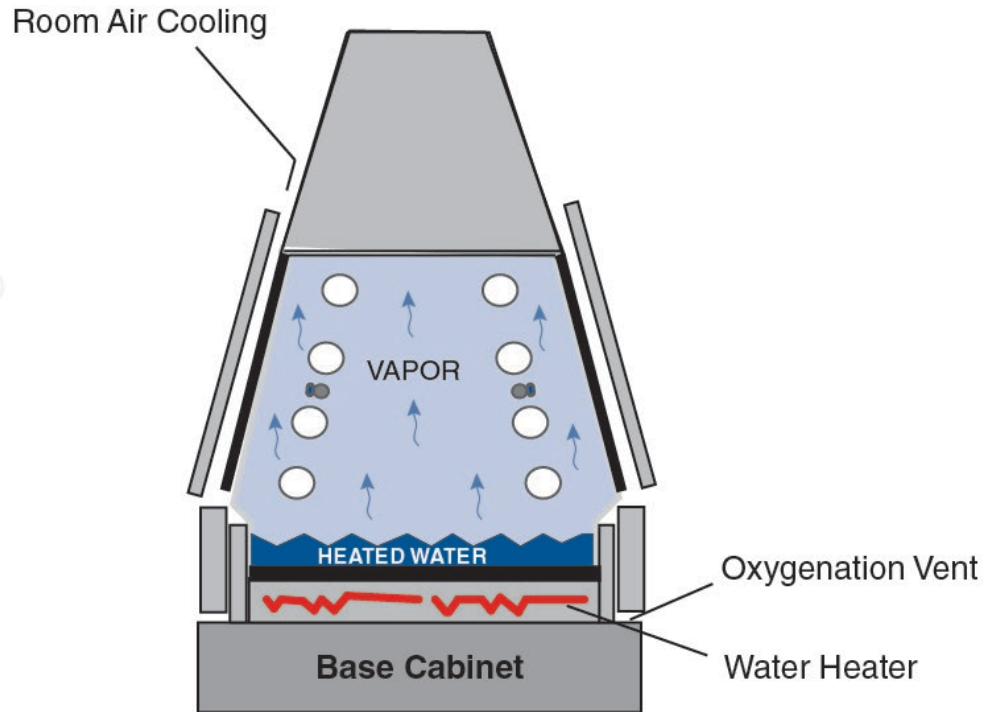
# Temperature & Color

## Temperature difference between colored panels and Black Panel



*Fischer and Ketola, 1993*

# Condensation



# Condensation Advantages

- Closest match to natural wetness
- Best way to accelerate water in an laboratory tester
- Elevated temperature
- High O<sub>2</sub> 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*

# Water Spray

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



*Creating spray in the QUV is difficult and relatively expensive*

# Fluorescent UV Summary

- UVA-340 best simulation of short-wave UV
- UVB-313 fastest & most severe
- Stable spectrum – no aging
- No visible light
- Condensation realistic & rigorous
- Water spray available but not RH control

# QUV Accelerated Weathering Tester

## Model QUV/se



# Fluorescent UV and Xenon Arc

## Complementary Technologies

### Fluorescent UV

- UVA-340 best simulation of shortwave UV
- UVB-313 might be too severe
- No visible light
- Stable spectrum
- No RH control
- Condensation or water spray
- Inexpensive, simple to use

### Xenon Arc

- Full spectrum (UV-Vis-IR)
- Best simulation of long wave UV & visible light
- Spectrum changes
- RH control
- Water spray
- More complex system



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Predictive	Service life Acceleration factor	<ul style="list-style-type: none"><li>• Open-ended</li><li>• Long</li></ul>	Natural exposure (Service environment)

# Putting It All Together

- Identify the kind of accelerated test
  - Outdoor data is imperative to correlative and predictive testing
- Identify service environment
  - Indoor or Outdoor
  - Wet or Dry
  - Hot or Cool

# Putting It All Together

- Use Best Practices
  - Run until a defined failure mode
  - Use multiple replicates
  - Perform evaluations and reposition frequently
- Pick an appropriate Test Architecture
  - What does the standard say?
  - Is full spectrum important?
  - How important is water uptake?

# Thank you for your attention!

## Questions?

Send your inquiry to:  
[info@q-lab.com](mailto:info@q-lab.com)

