The Essentials of Laboratory Weathering

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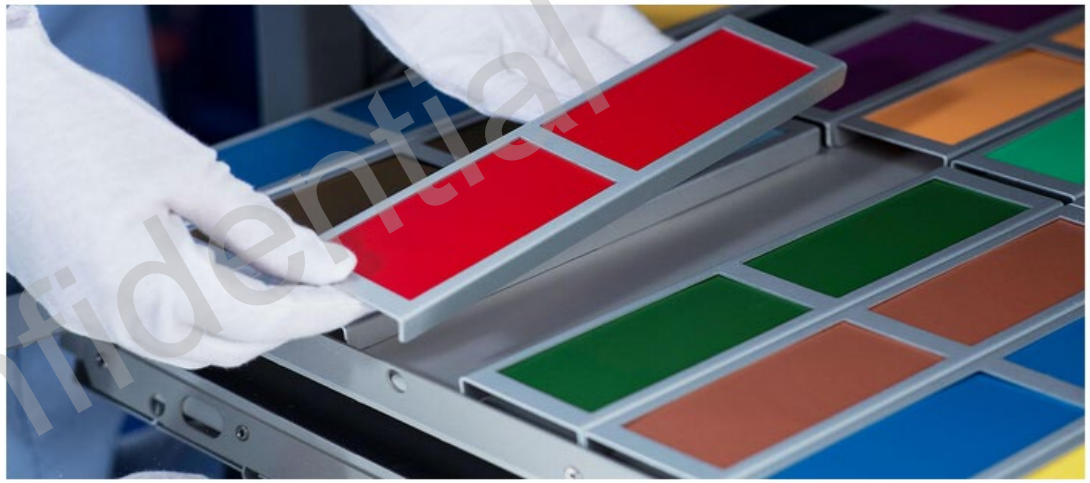

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We hope you found our webinar on *Essentials of Laboratory Weathering* to be helpful and insightful. The link below will give you access to the slides and recorded webinar.

You can help us continue to provide valuable and high quality content by completing our 3-question survey about your webinar experience. Every piece of feedback is carefully reviewed by a member of our team.

What We Will Talk About

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

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

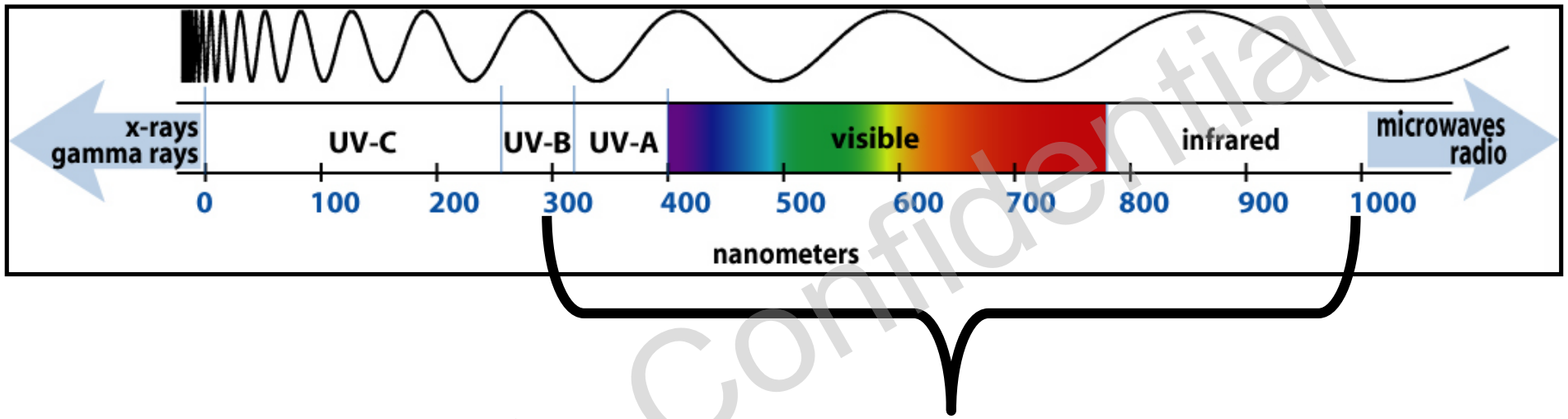
**Other factors can impact weathering as well but we will not focus on those today*

Sunlight

Sunlight

- A form of energy
- Electromagnetic radiation
- Usually described in terms of **irradiance** & **wavelength (λ)**

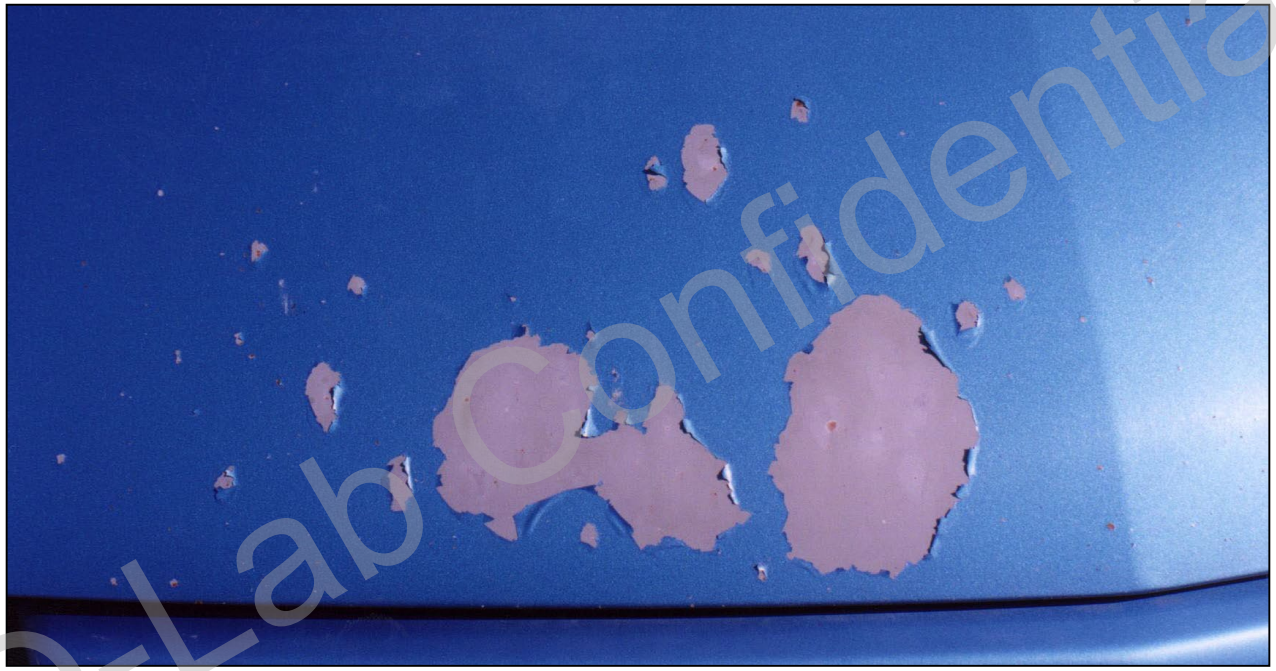
Electromagnetic Spectrum



Sunlight

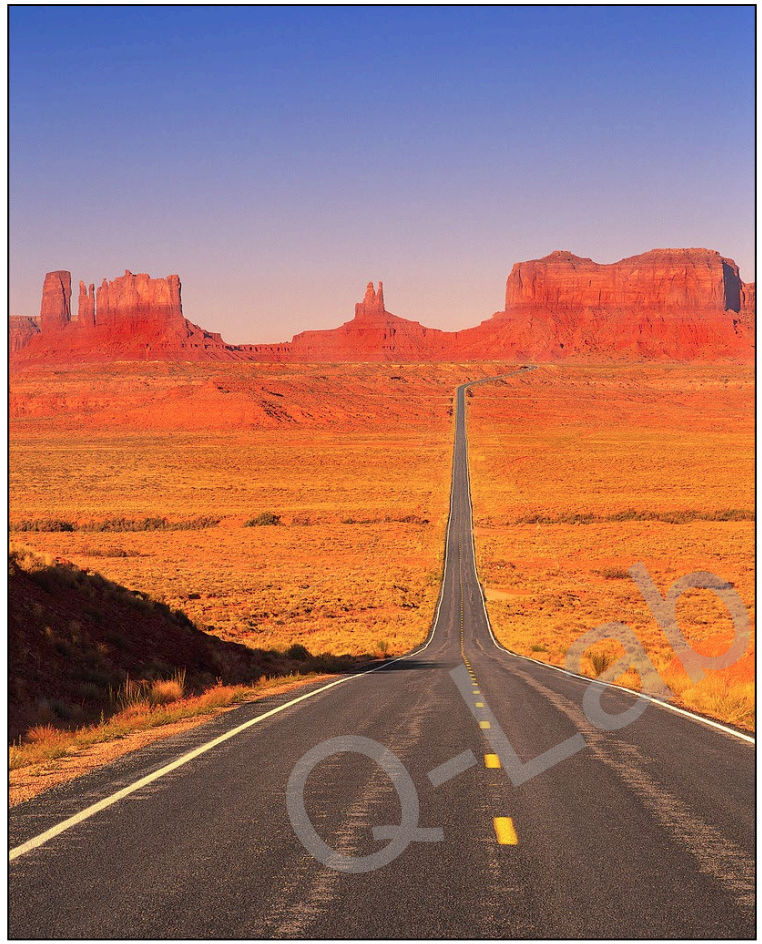
UV	**295-400 nm**	**~7%**
Visible	400-800 nm	~55%
IR	800-3000 nm	~38%

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



UV causes virtually all polymer degradation!

Irradiance



Irradiance[1] is the rate at which light energy falls on a surface, per unit area

[W/m^2] or [$J/s \cdot m^2$]

Spectral irradiance[2] is the irradiance of a surface per unit wavelength

[$W/m^2/nm$]

Radiant exposure[1] (or **radiant dosage**) is irradiance over a period of time

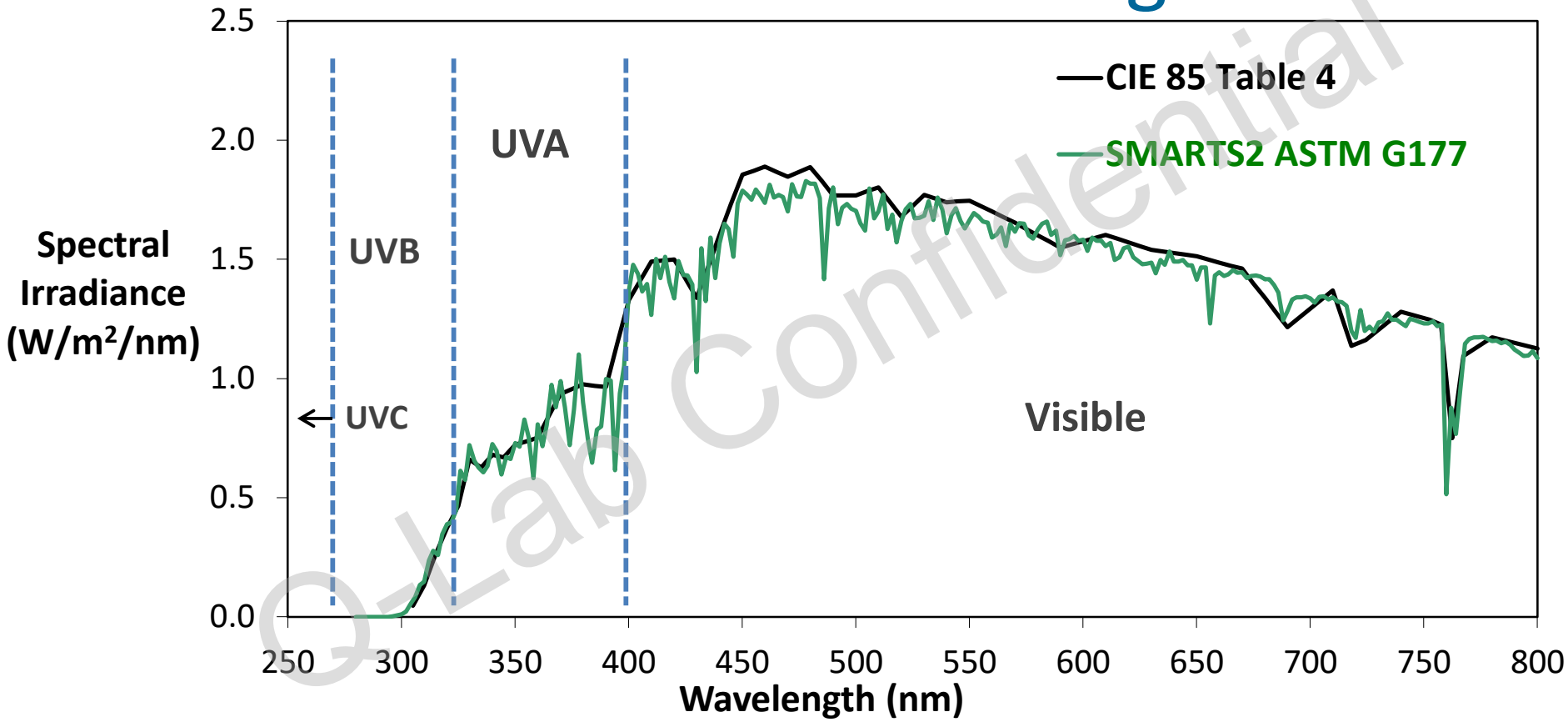
[J/m^2] or [$W \cdot s/m^2$]

[1] *ASTM G113 –Terminology*

[2] *ISO 9288 – Physical quantities and Definitions*

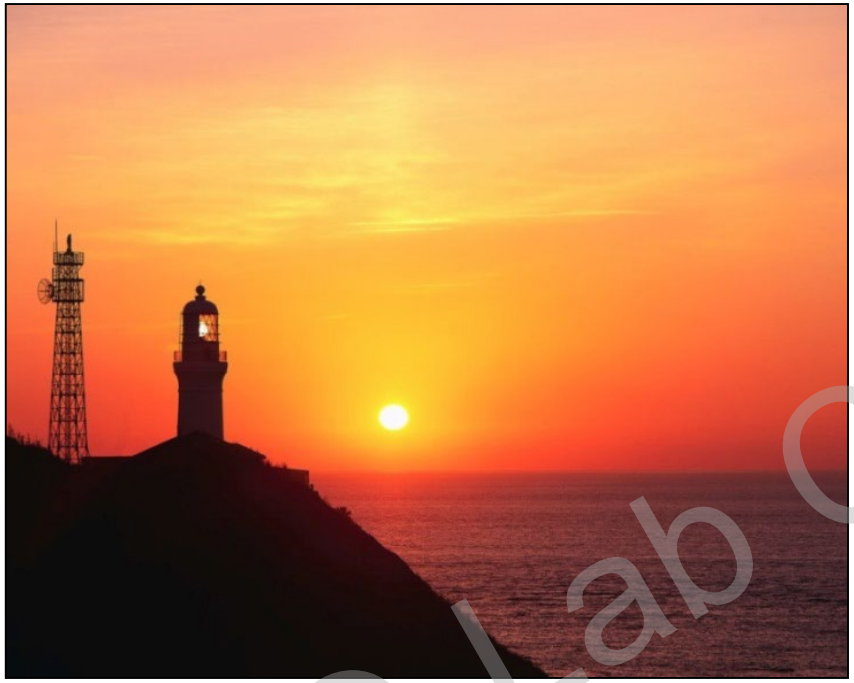
Spectral Power Distribution (SPD)

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

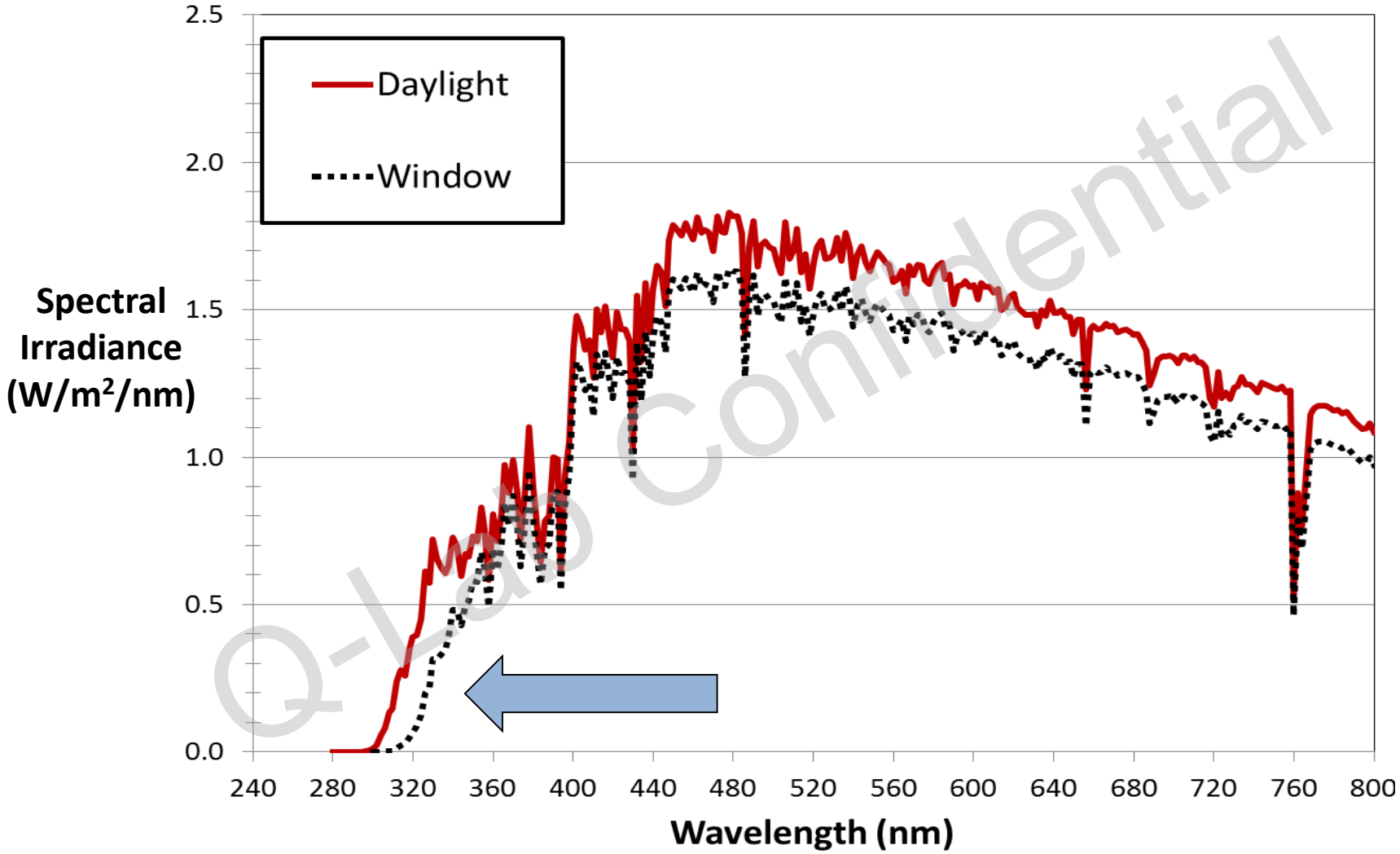


Sun angle

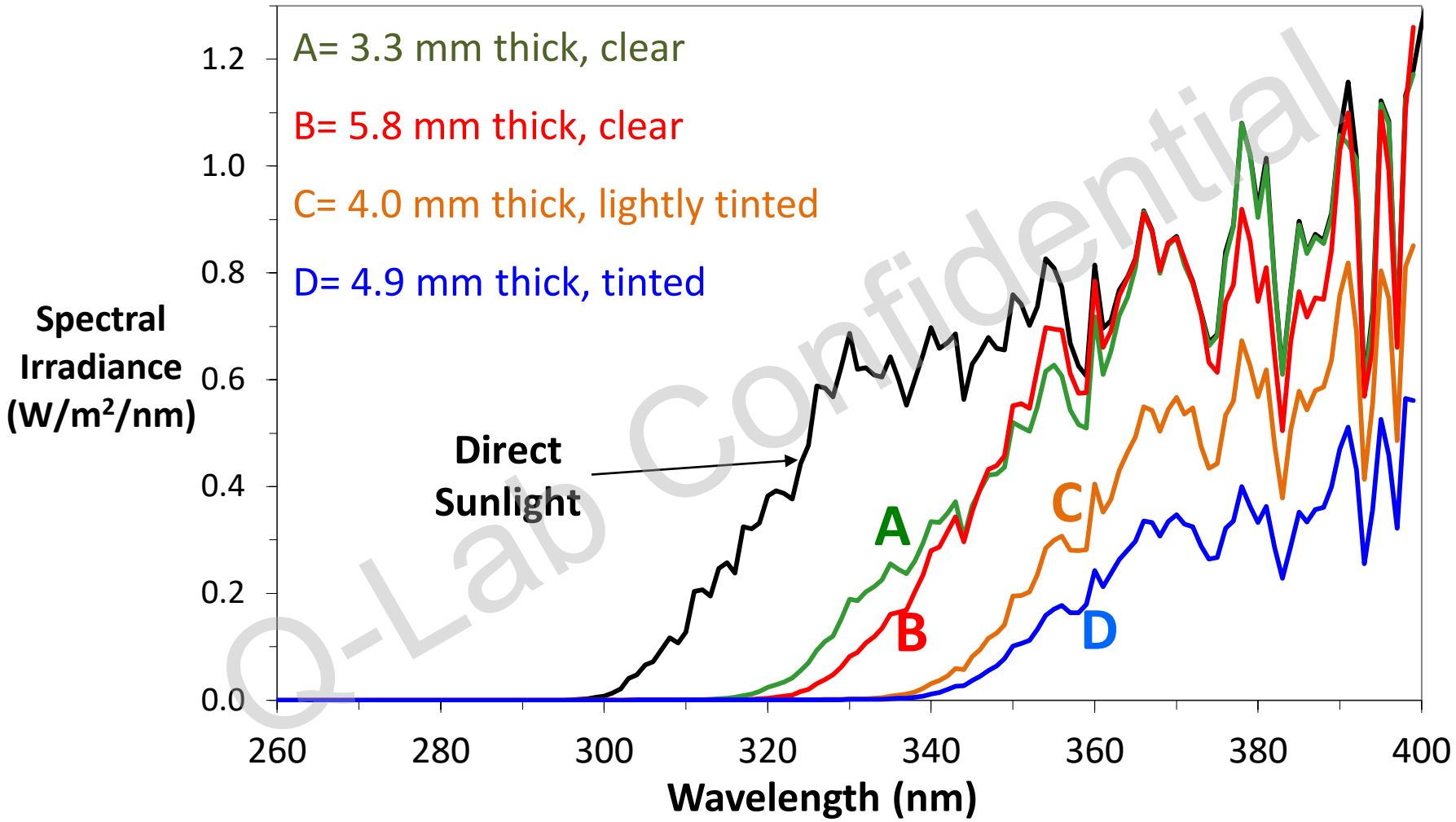
- Time of Year (e.g. summer)
- Time of Day (e.g. noon)
- Latitude

Altitude

Sunlight Through Window Glass



Sunlight Through Automobile Glass



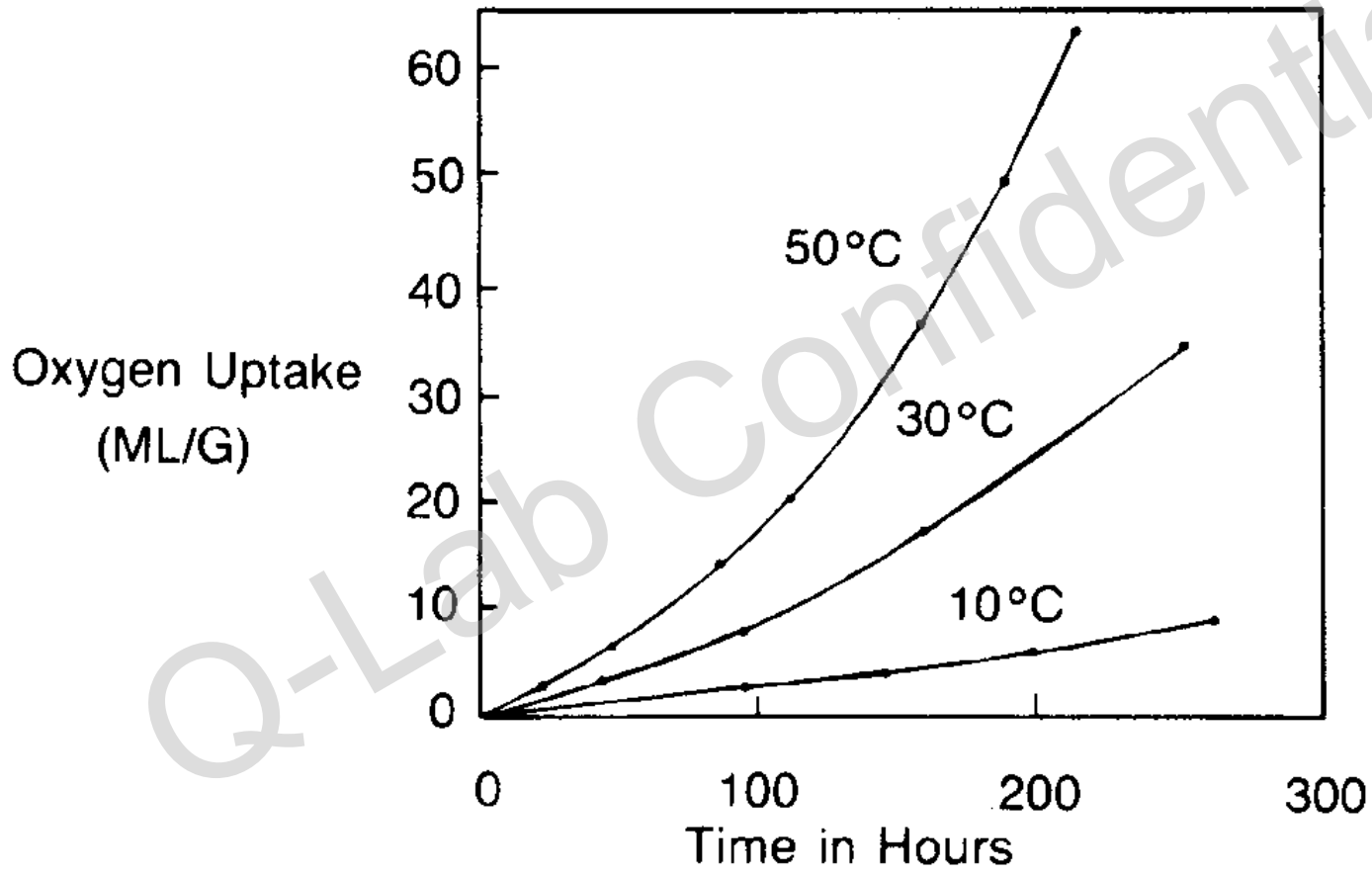
Heat

Heat Effects

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

Effect of Temperature:

Oxidation Rate of Polyethylene



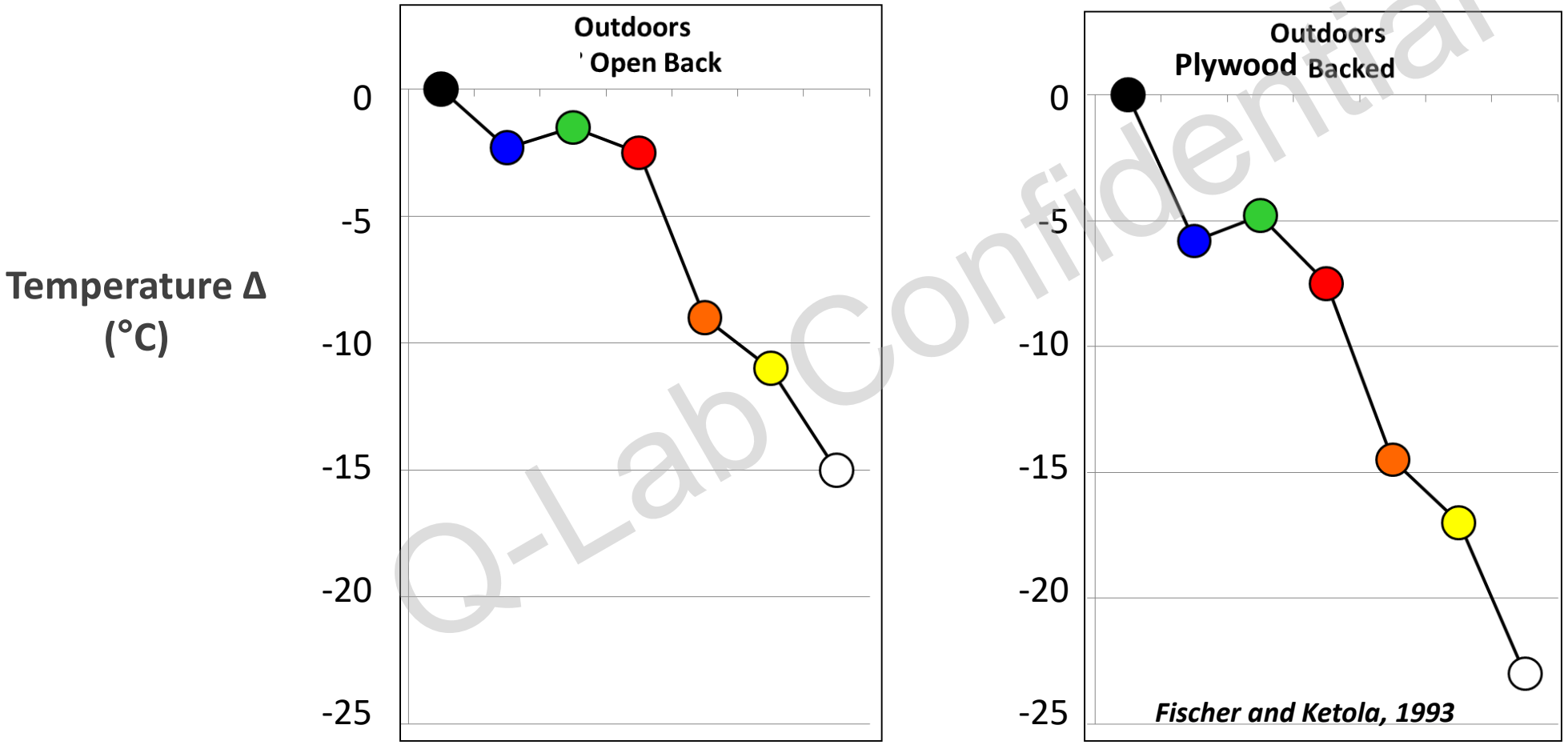
**Time In Hours Exposed to UV lamps*

Thermal Cycling in Florida

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

Temperature and Color

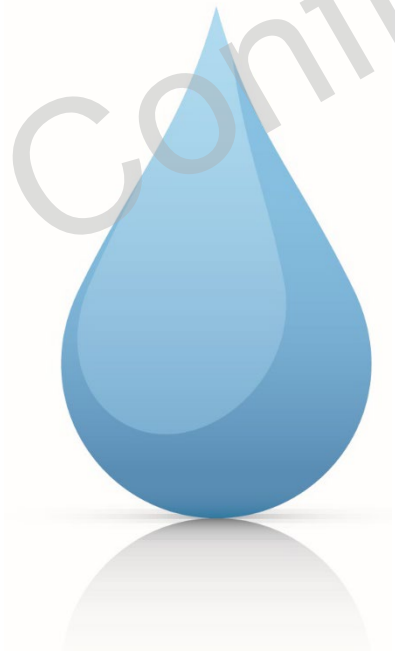
Darker Colors Have Higher Temperatures!



Heat behind Window Glass

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

Water



Major Effects of Water

Chemical Reactions

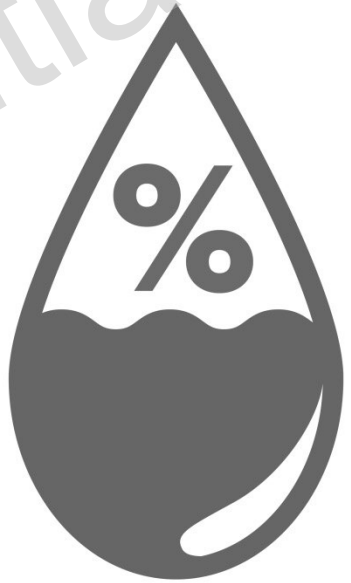
- Reactions in solution
- Facilitates reaction via increase in oxygen transport

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

Moisture from the atmosphere that forms in the form of small drops upon any cool surface

High O_2

Long Dwell Time

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

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

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- **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	• Defined • Short	Material specification

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Correlative	Rank-ordered data	• Open-ended • Medium	Natural exposure (Benchmark site)

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Correlative	Rank-ordered data	• Open-ended • Medium	Natural exposure (Benchmark site)
Predictive	Service life Acceleration factor	• Open-ended • Long	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

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- **Laboratory Weathering Testing**
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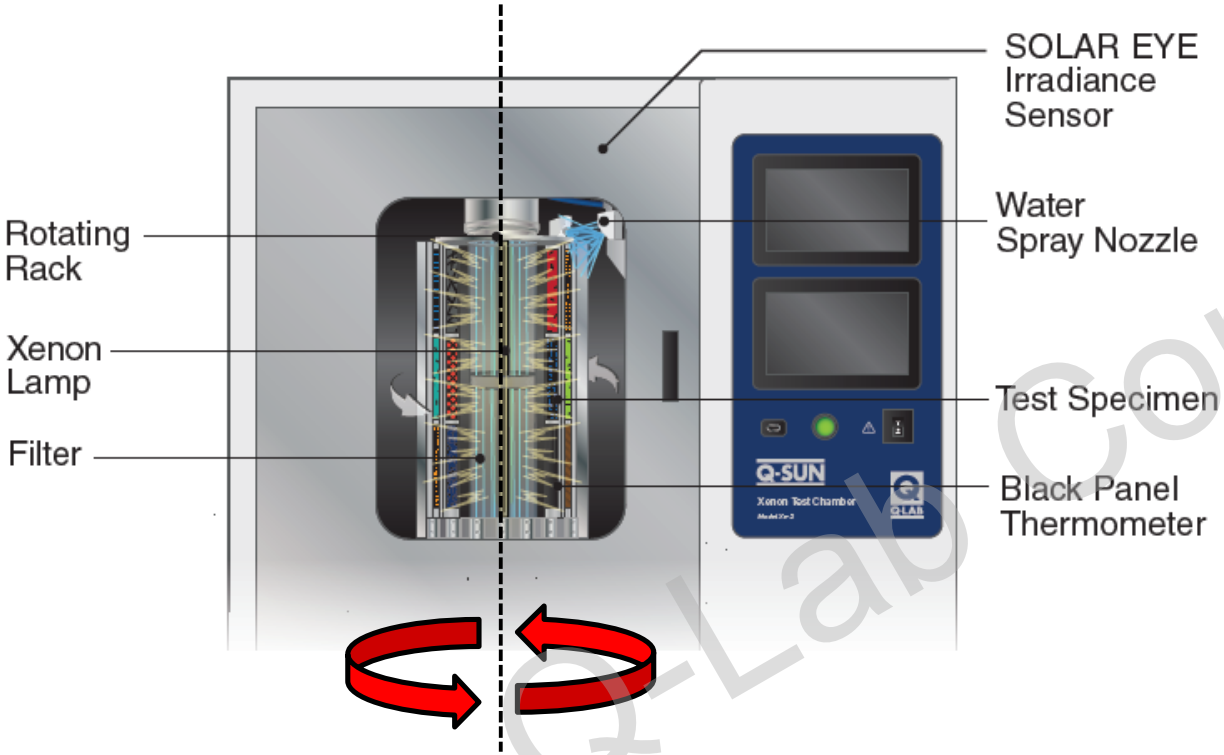
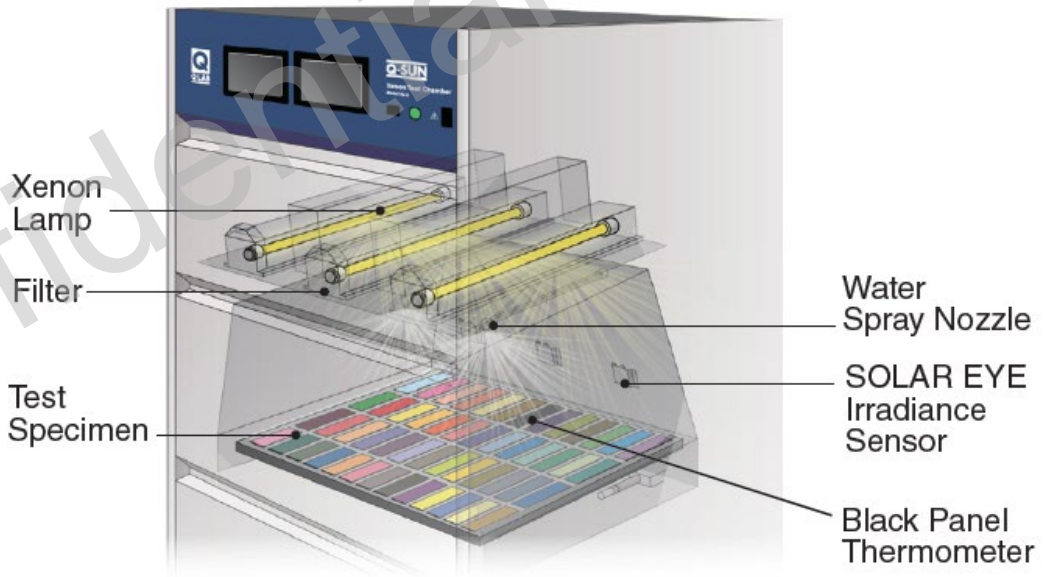
  - **Fluorescent UV**
- Elements of an Effective Testing Program

Xenon Arc Laboratory Weathering

Xenon Arc Test Chamber



Rotating Drum



Flat Array

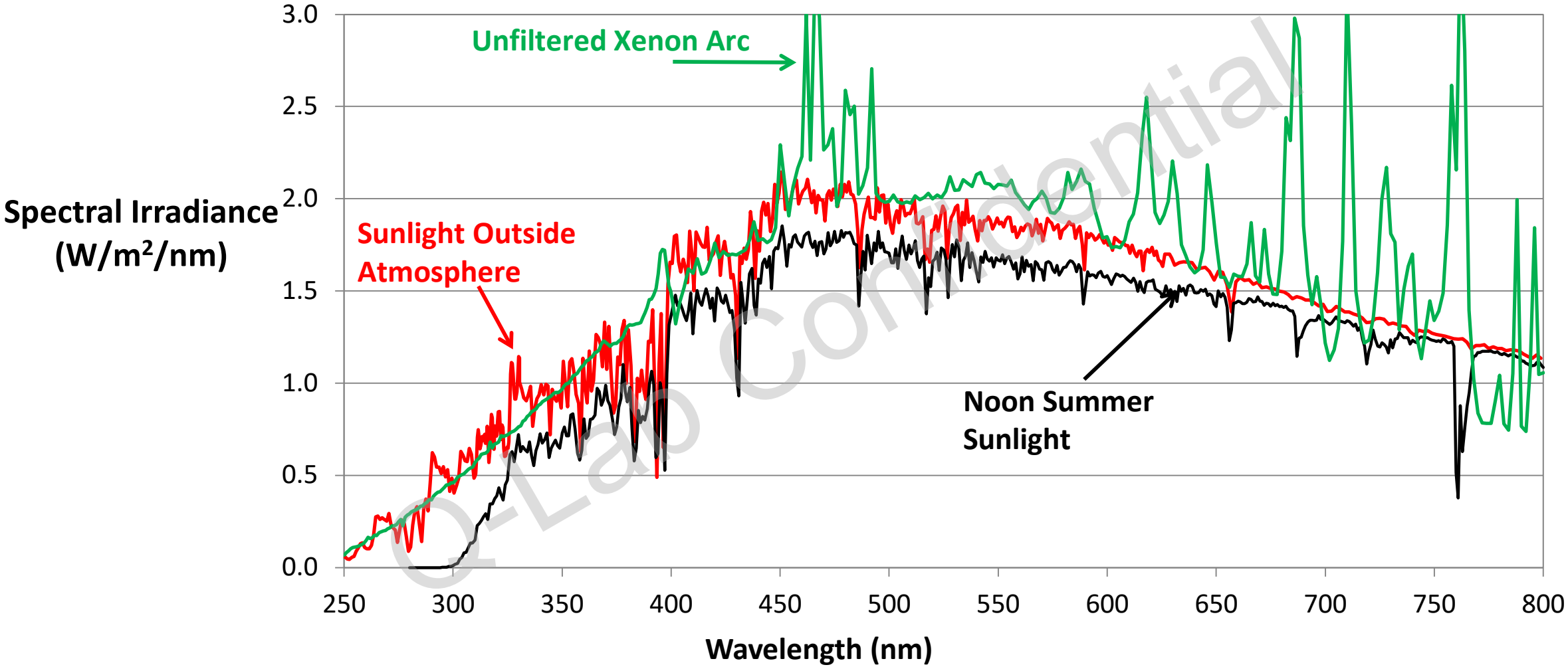
Xenon Arc Lamps

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

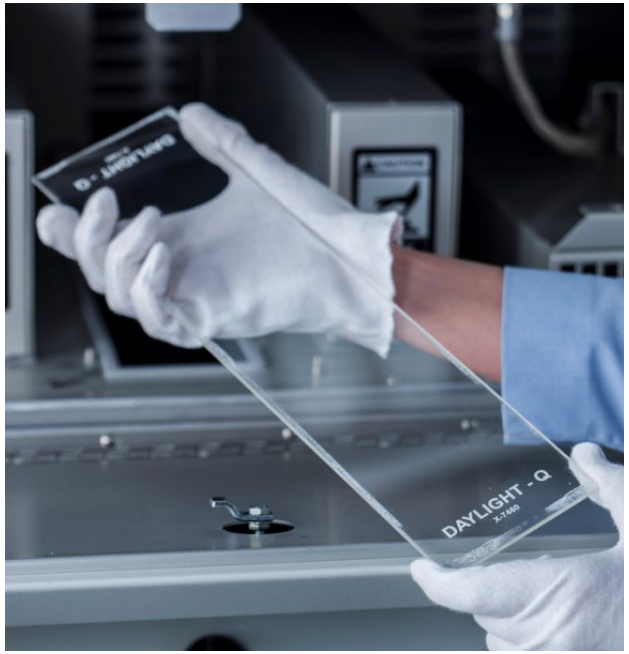


Overview of Filters

- Daylight
- Window
- Extended UV

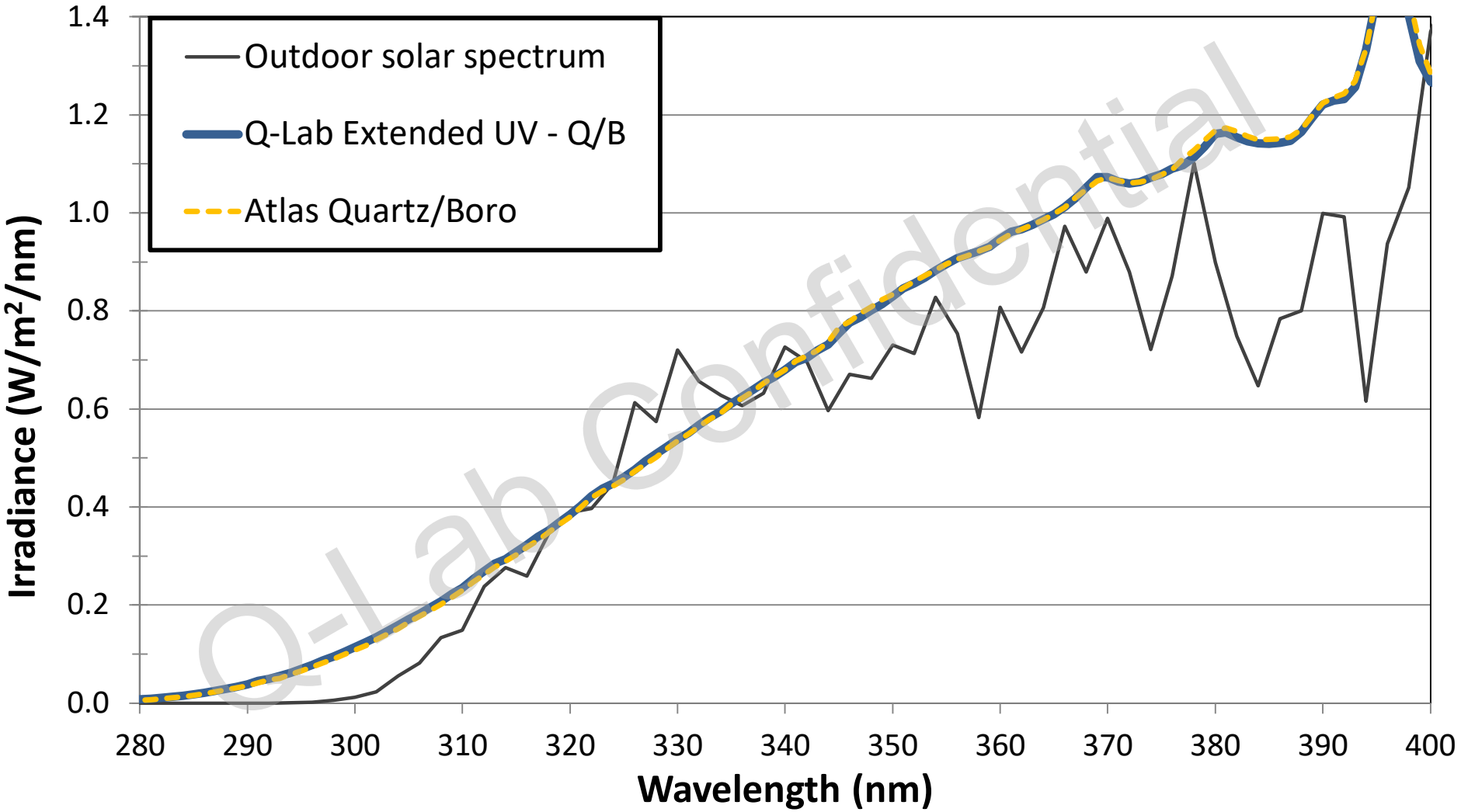
Rotating drum "lantern"

Flat array filter

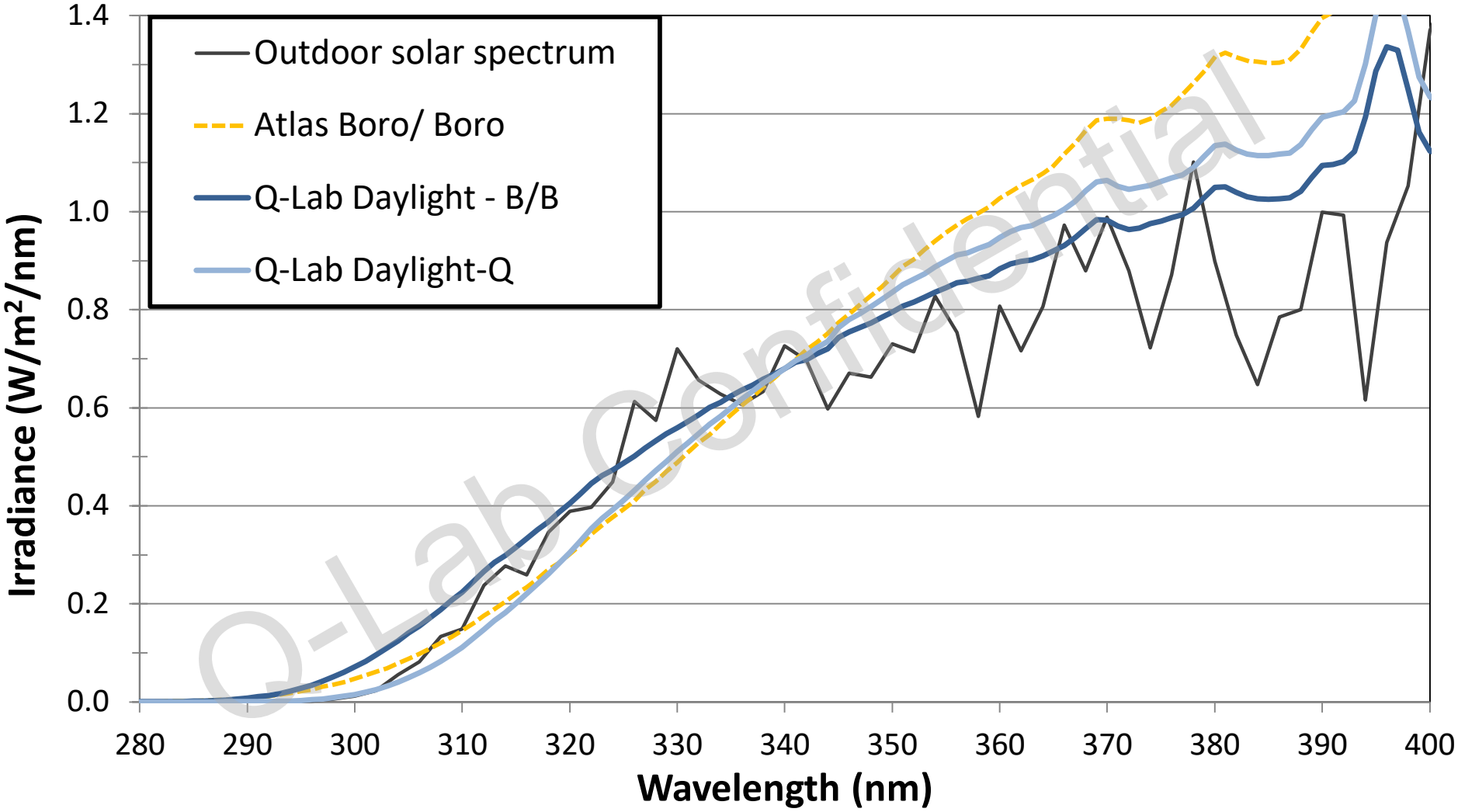


**Other specialized filters used occasionally*

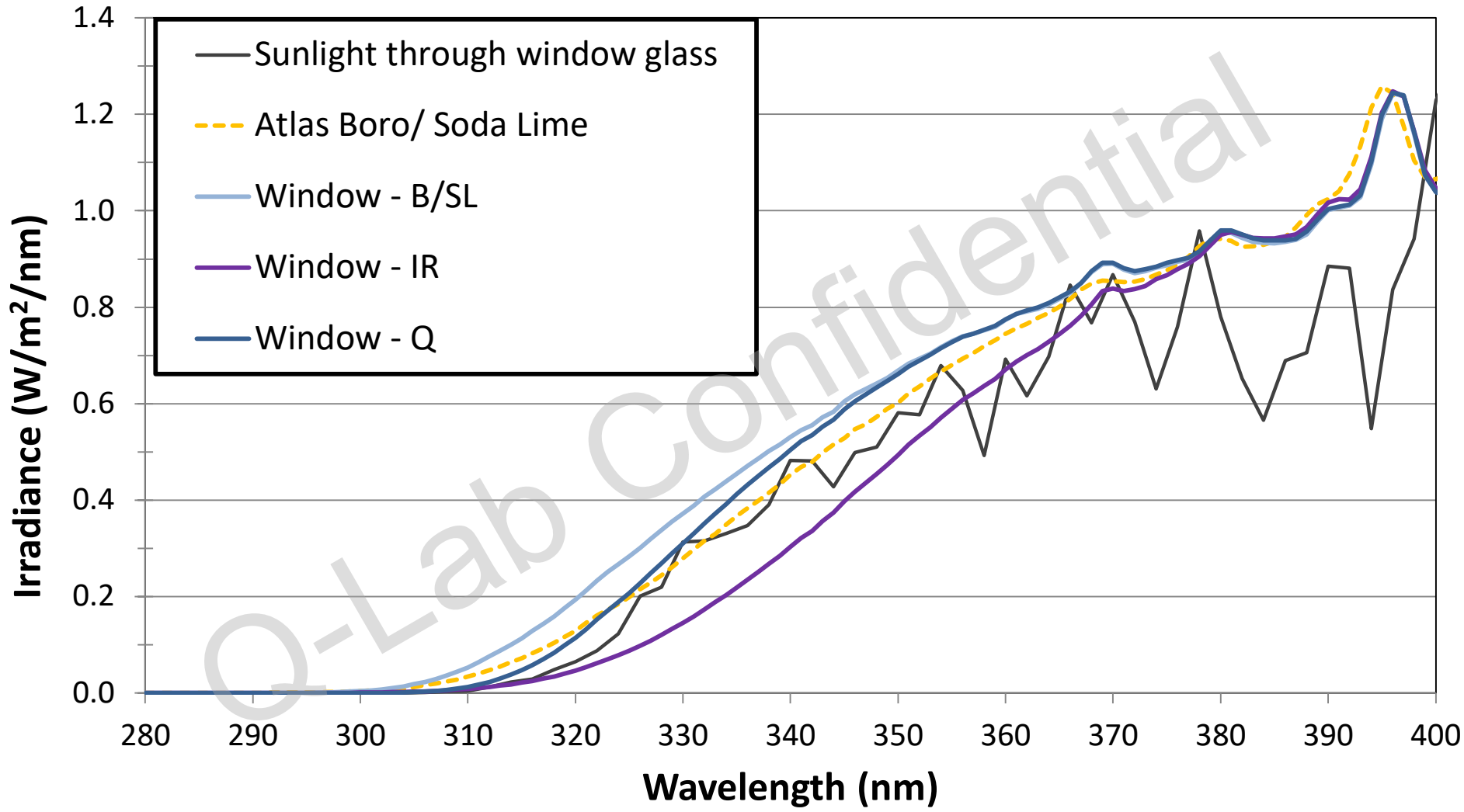
Extended UV Filter Comparison



Daylight Filter Comparison



Window Filter Comparison



Optical Filter Aging
Water-Cooled vs Air-Cooled

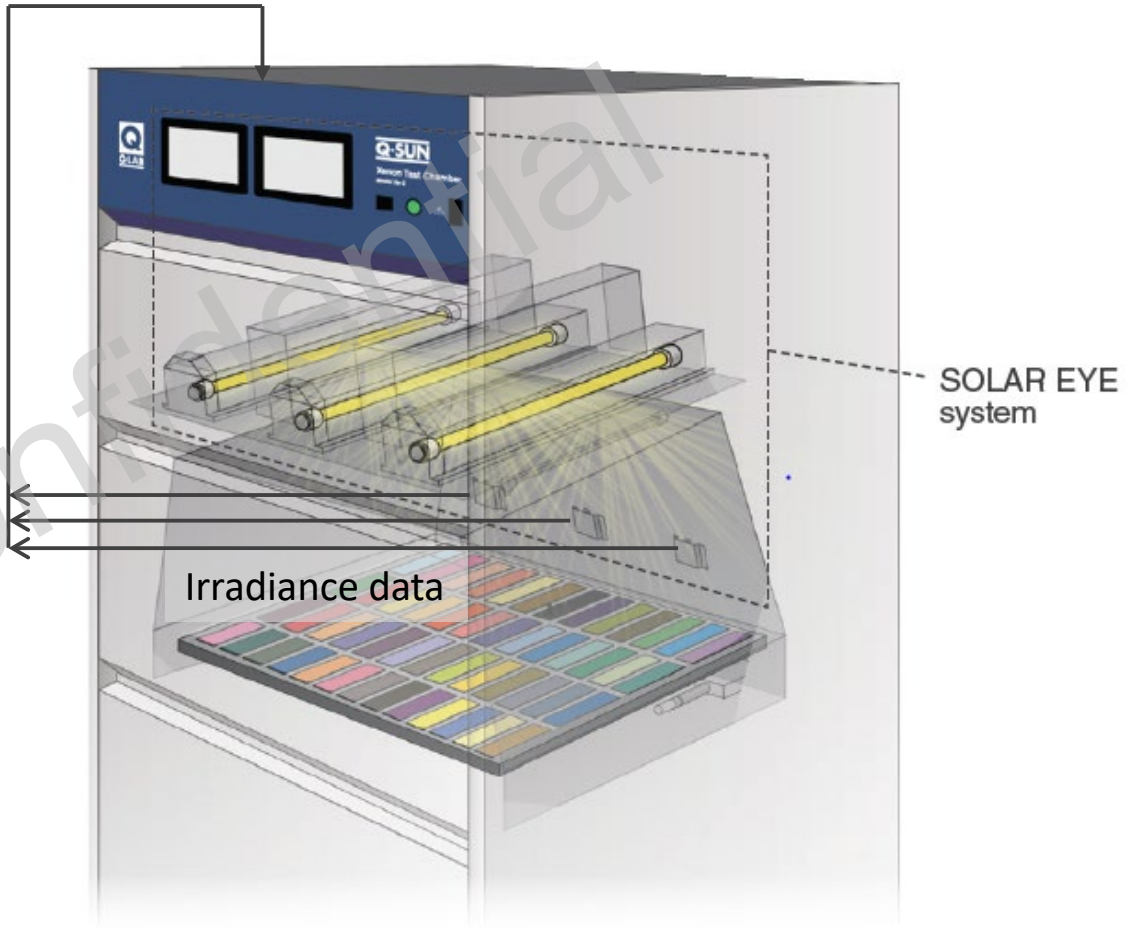
- Filters for water-cooled lamp systems need to be replaced every 400-2000 hours
  - Contaminants, even in ultra-pure de-ionized water, reduce filter transmittance over time
- Almost all filters for air-cooled lamp systems do not age or need to be replaced

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

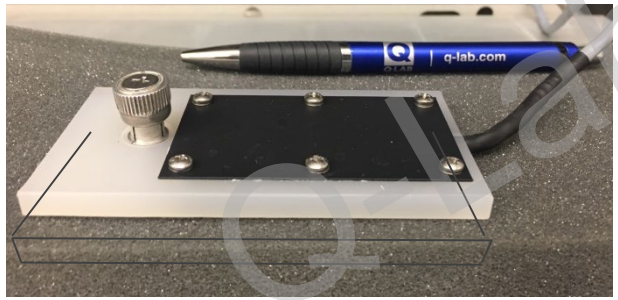
Why Is Choice of Control Point Important?

- 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
	Black painted stainless steel	Uninsulated Black Panel	Black Panel
	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 (SAE)
- 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

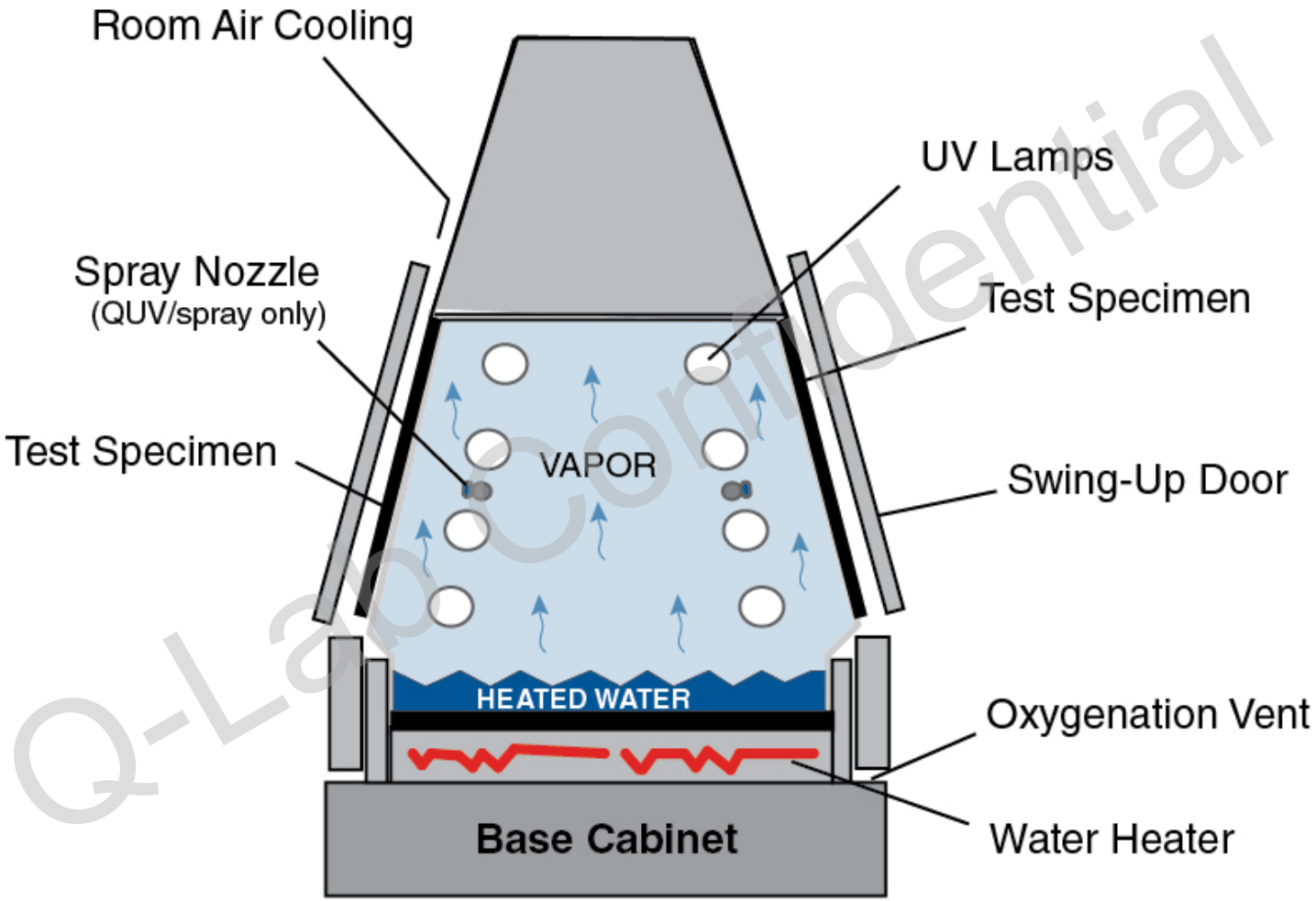
Xe-1

Xe-2

Xe-3

Fluorescent UV Laboratory Weathering

Fluorescent UV Schematic

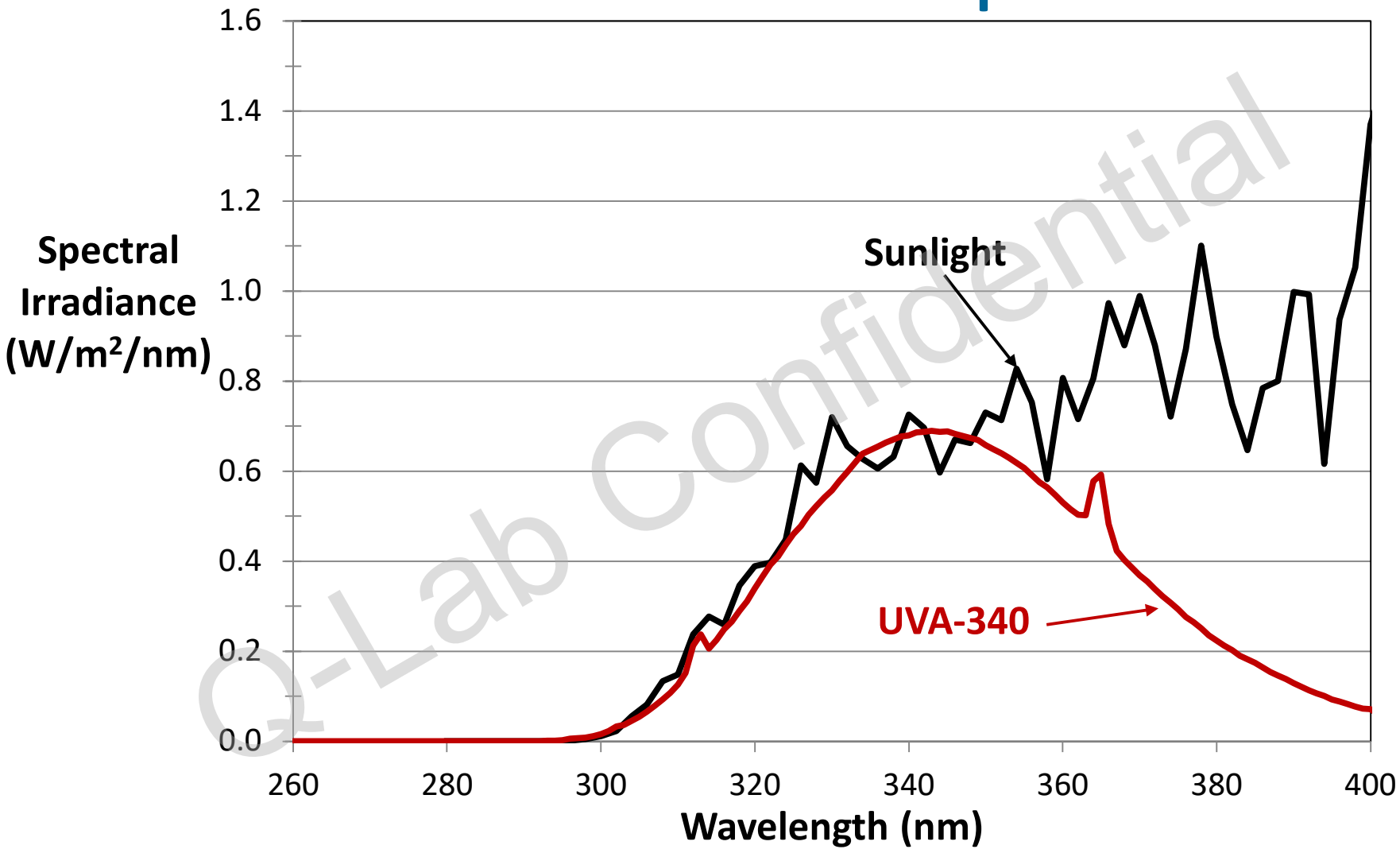


Fluorescent UV Lamp

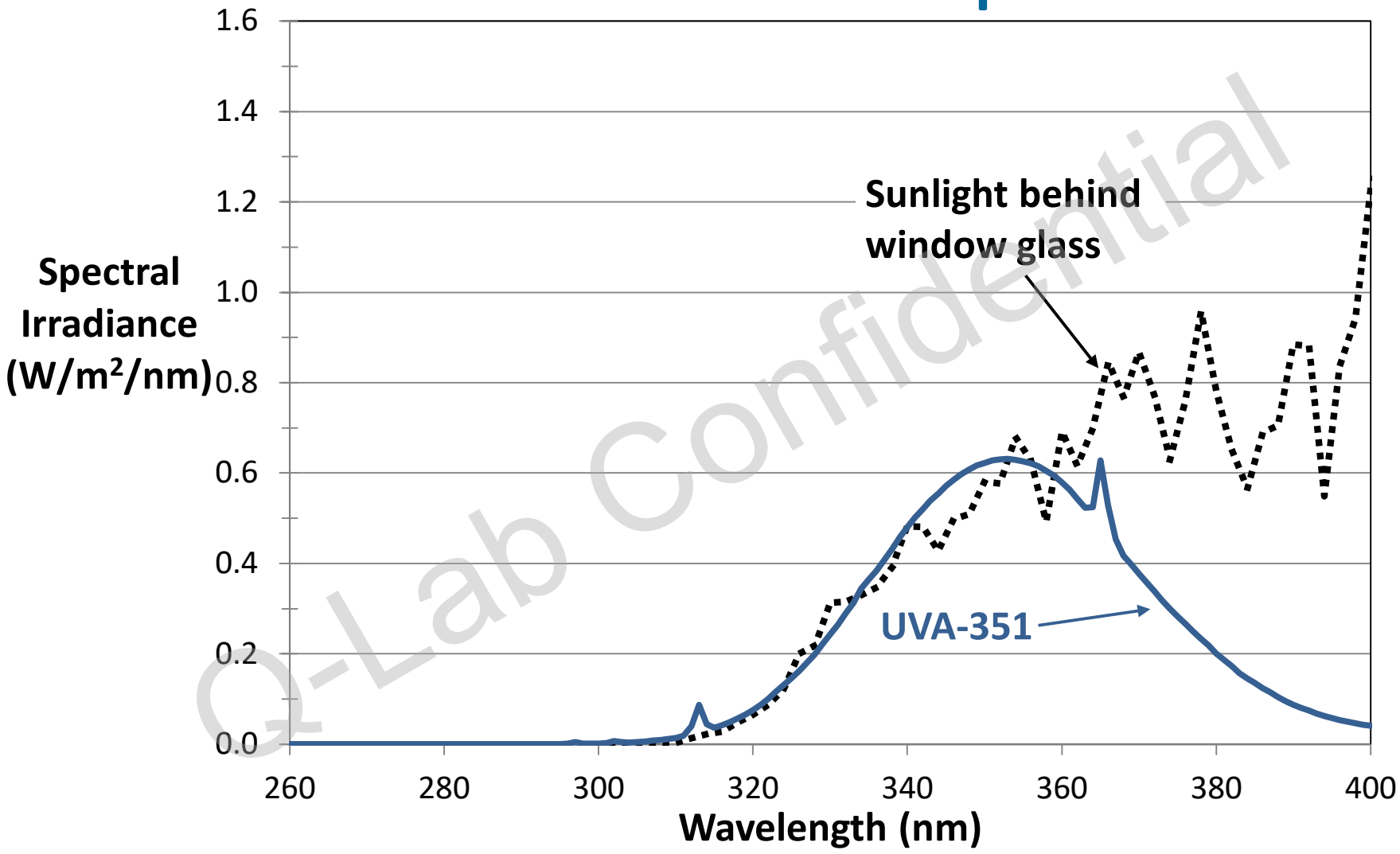
QUV Lamp Summary

- UVA-340 (Daylight UV)
- UVA-351 (Window UV)
- UVB-313EL/FS-40 (Extended UV)
- Cool White (Indoor)

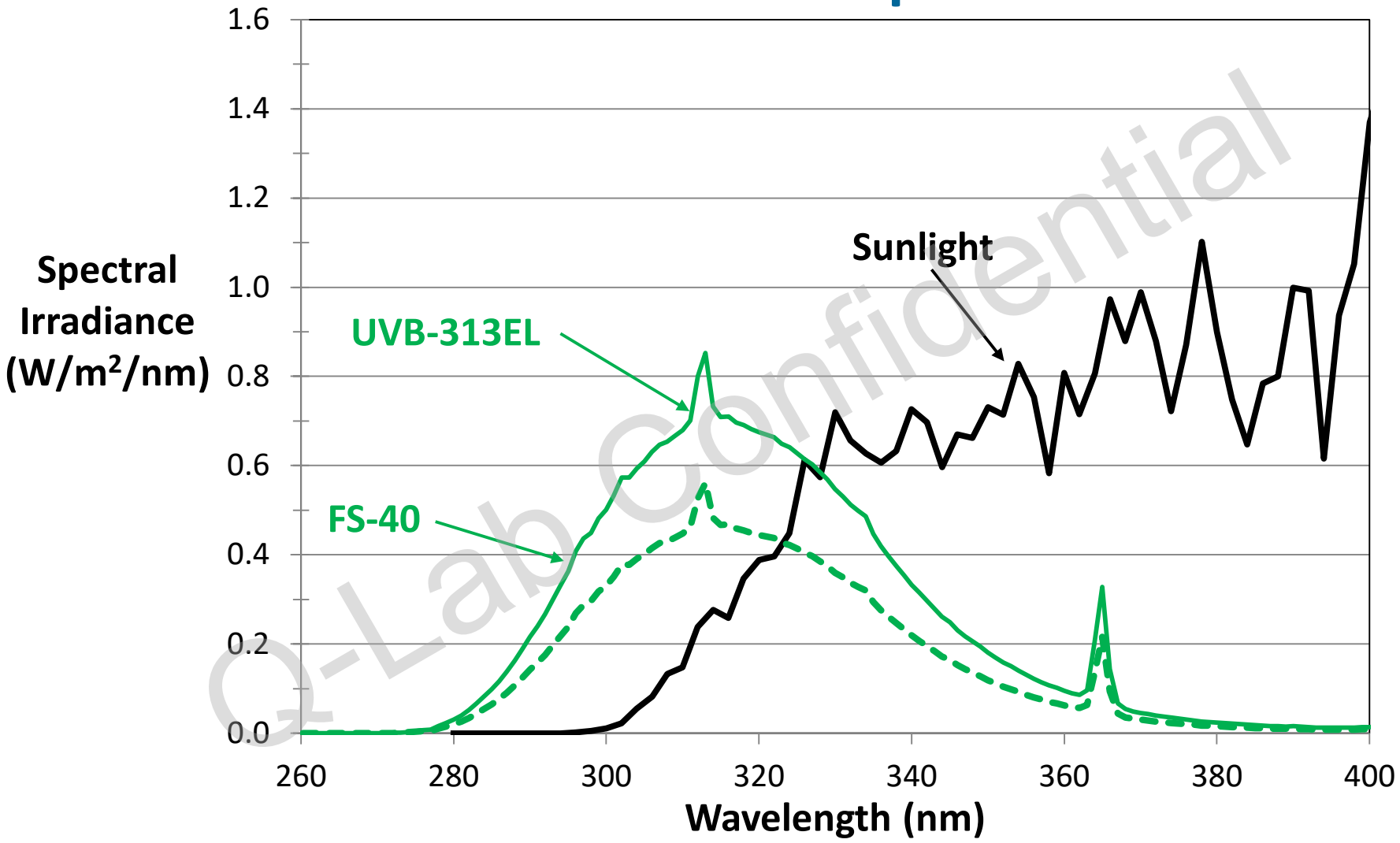
UVA-340 Lamps



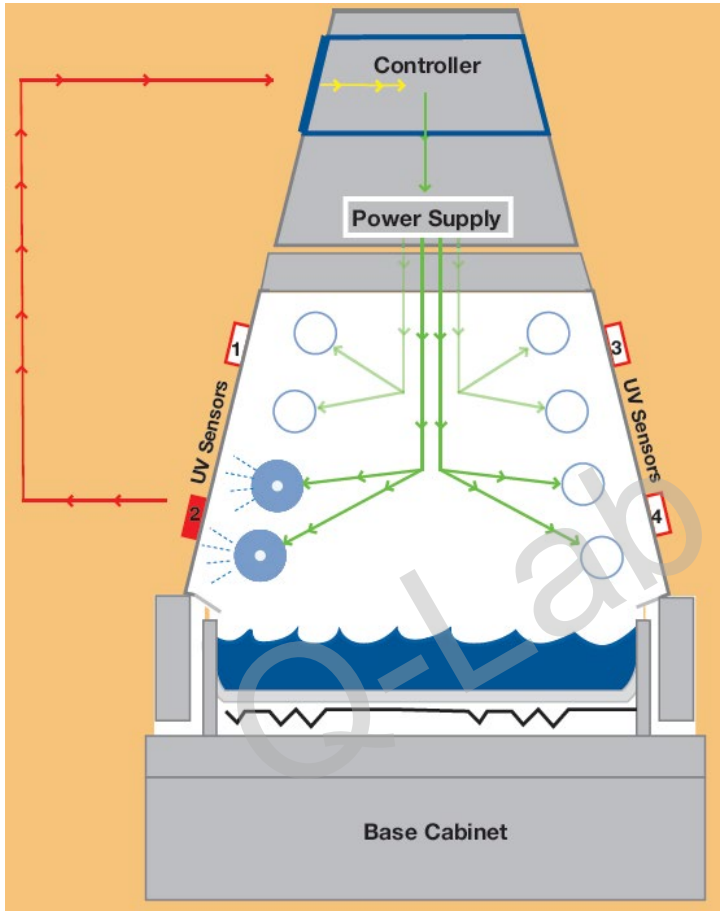
UVA-351 Lamps



UVB Lamps



QUV SOLAR EYE™ Irradiance Control



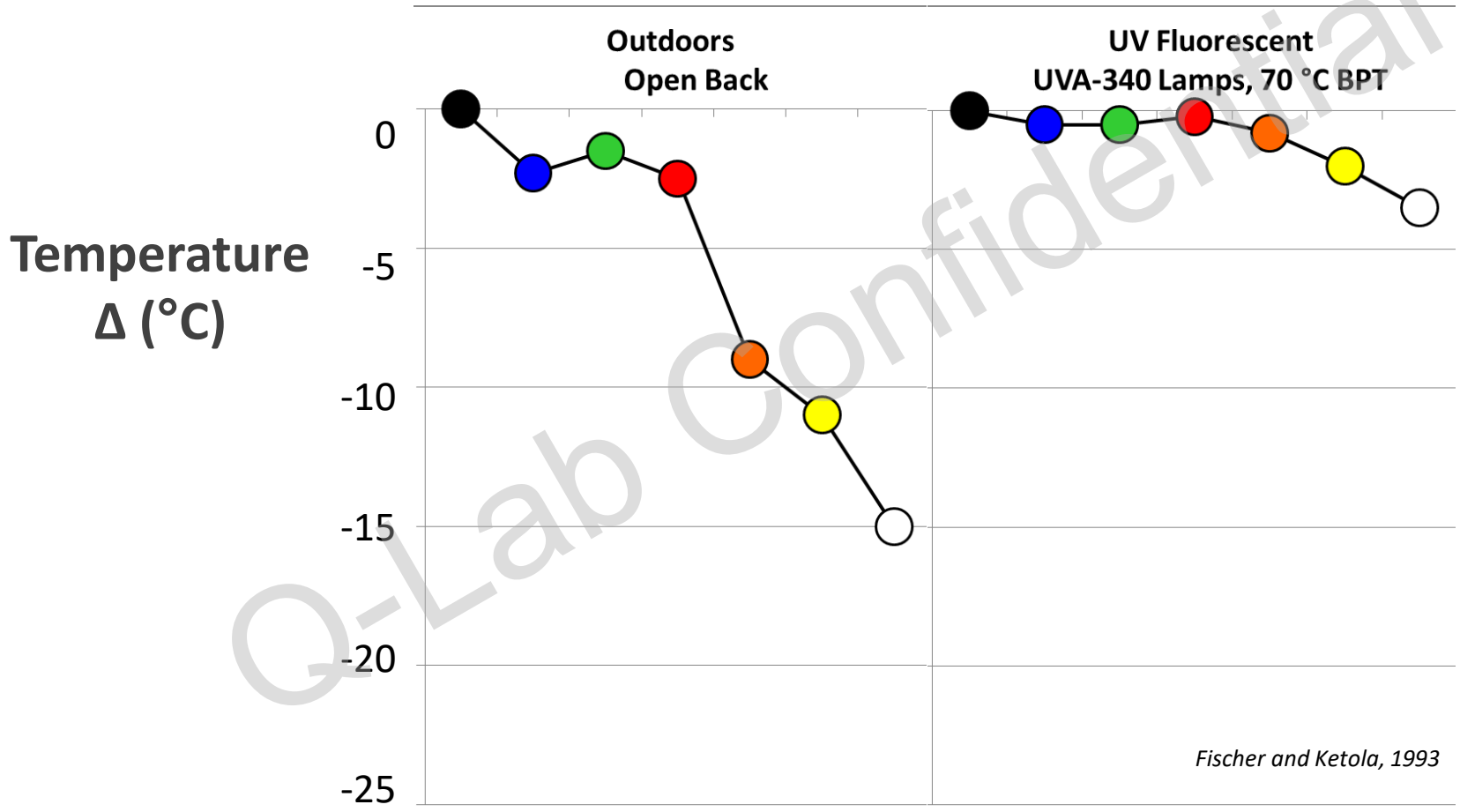
- Feedback Loop Control
  - Fluorescent UV lamp
  - Light sensor
  - Control module

Fluorescent Lamp Advantages

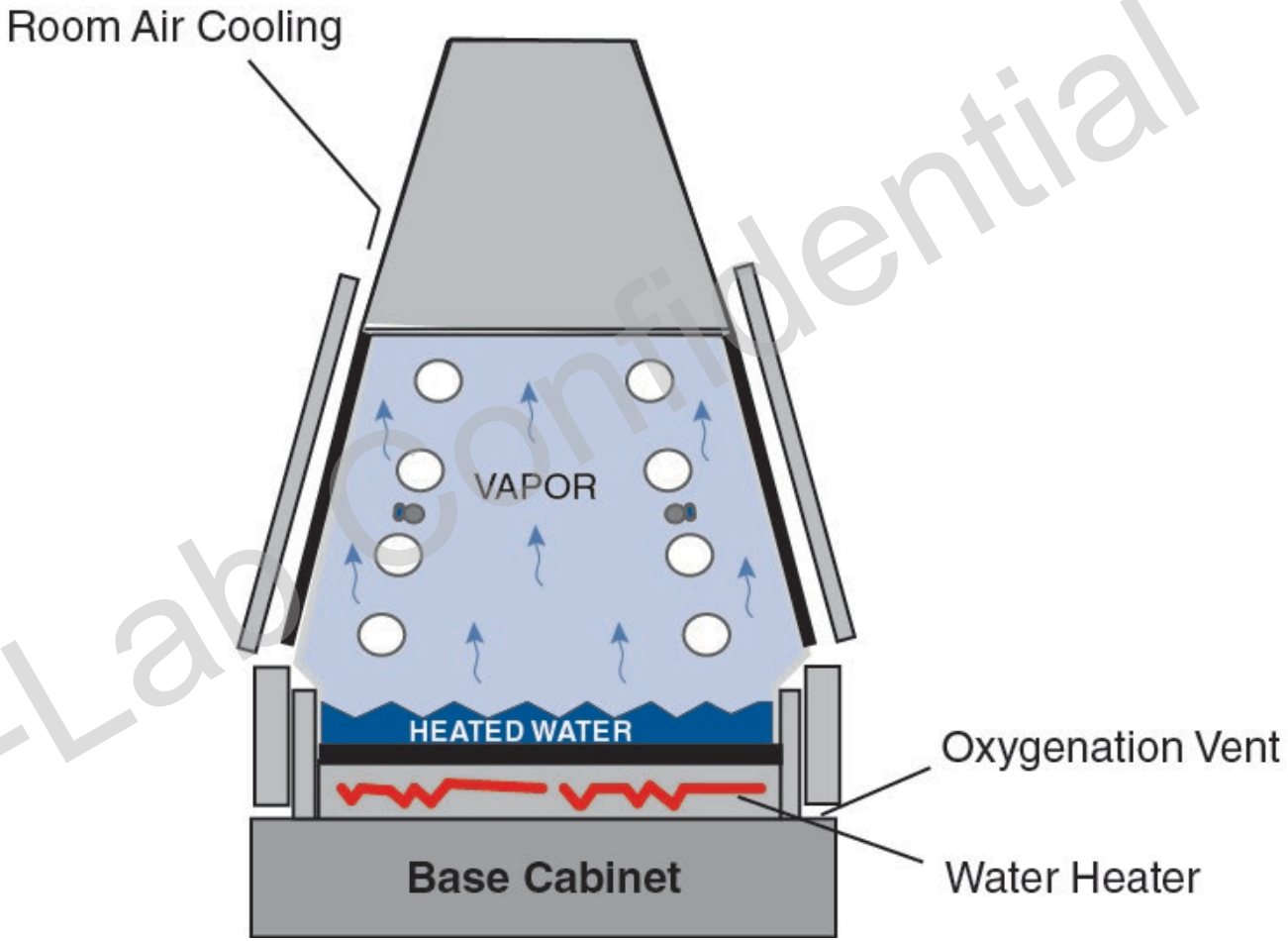
- Fast Results
- Simplified irradiance control
- Very stable spectrum – no aging
- Low maintenance
  - Simple calibration
- Low price and operating cost
- Simple and easy to maintain

Temperature & Color

Temperature difference between colored panels and Black Panel



Condensation



Condensation Advantages

- 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

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	Xenon Arc
• UVA-340 best simulation of shortwave UV	• Full spectrum (UV-Vis-IR)
• UVB-313 might be too severe • No visible light	• Best simulation of long wave UV & visible light
• Stable spectrum	• Spectrum changes
• No RH control	• RH control
• Condensation or water spray	• Water spray
• Inexpensive, simple to use	• More complex system

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Predictive	Service life Acceleration factor	• Open-ended • Long	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?

Questions?

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