

내후성 시험의 필수 요소

Essentials of Laboratory Weathering

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Q-Lab Corporation

녹음하기

Administrative Notes

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 make testing simple.



Thank you for attending our webinar!

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

Q-Lab Corporation

- 1956 창업
- 내후/내광성/부식 시험 전문 기업



Westlake, Ohio
Headquarters &
Instrument Division



볼튼, 영국
Q-Lab(社) 유럽



상하이, 중국
Q-Lab(社) 중국



자르뷔르켄, 독일
Q-Lab(社) 독일

Q-Lab Outdoor/Accredited Lab





Exciting
News!

Q-Lab is excited
to announce the
acquisition of

Arizona Desert Testing, LLC!

We make testing simple.

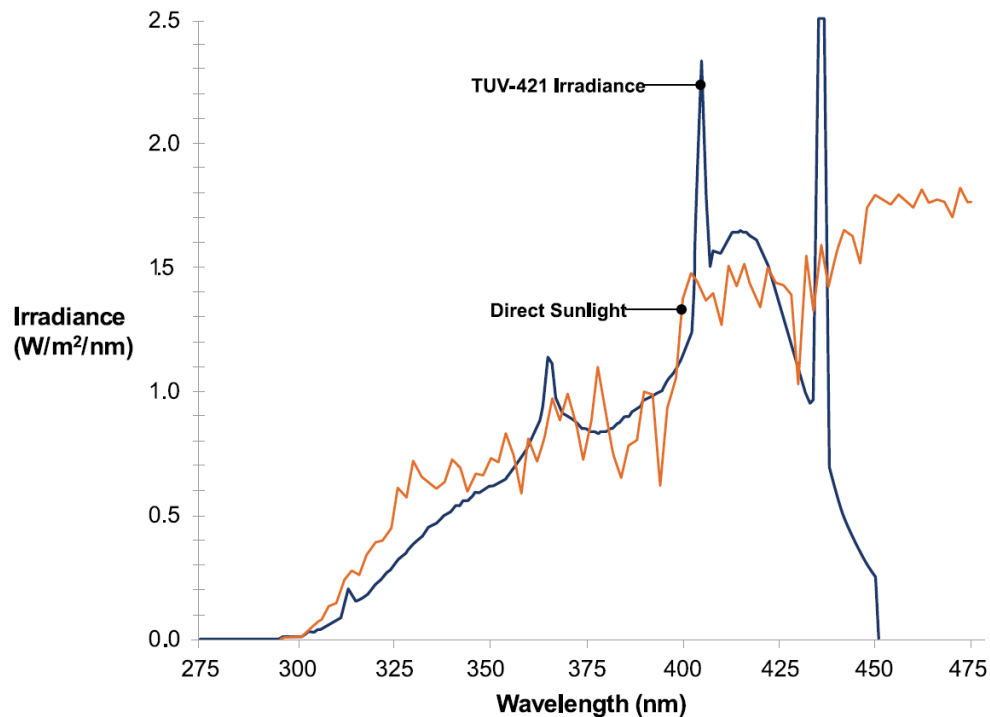


Q-SUN Xe-8

The NEW standard for large capacity, rotating rack xenon weathering testers



TUV-421 Lamps for QUV



What We Will Talk About

- **내후성의 기초** Basics of Weathering
- **내후성 실험을 하는 이유** Why Perform Laboratory Weathering?
- **내후성 실험** Laboratory Weathering Testing
 - Xenon
 - Fluorescent UV
- **효과적인 테스트 프로그램의 요소** Elements of an Effective Testing Program

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Weathering:

물질이 대기 환경에 노출되어 **햇빛** 및 **열**(온도 변화에 따른),
수분(주로 습기, 이슬, 강우 등) 인자의 복합적 영향으로 변화되는
것을 의미

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.



Sunlight



Heat



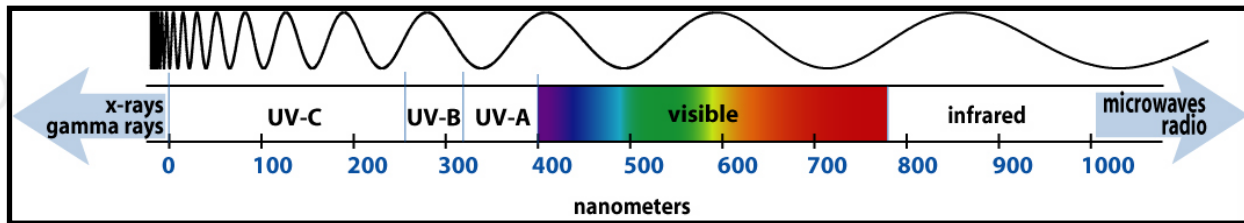
Water

Sunlight

- 에너지의 형태 A form of energy
- 전자기파 복사 Electromagnetic radiation
- 일반적으로 **조도& 파장** 으로 표현
described in terms of irradiance & wavelength (λ)



Electromagnetic Spectrum

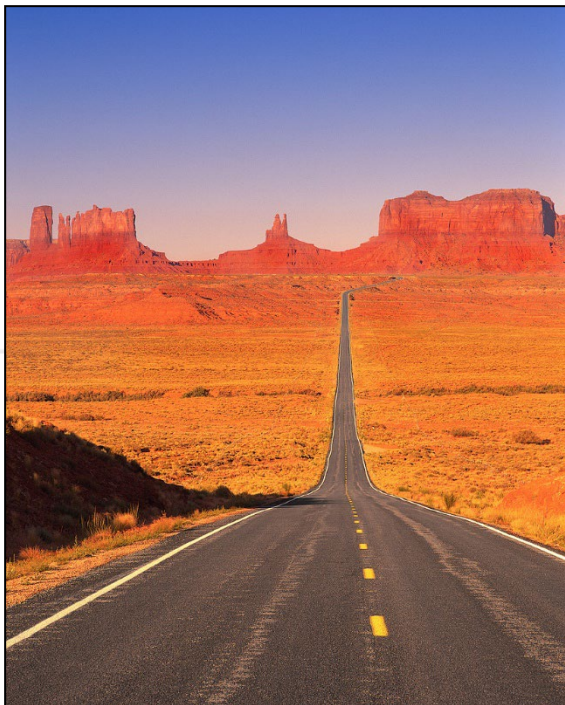


Sunlight

UV는 사실상 모든
폴리머 품질저하의 원인
UV causes virtually all polymer
degradation!

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

Irradiance



조도(Irradiance)¹

단위 면적당 빛 에너지가 표면에 떨어지는 비율

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

스펙트럼 조도(Spectral irradiance)² 단위 파장 당 표면 조도

$[W/m^2/nm]$ / $[mW/cm^2/nm]$

복사 노출(Radiant exposure)¹ (또는 복사용량(radiant dosage))

일정 기간 동안의 조도

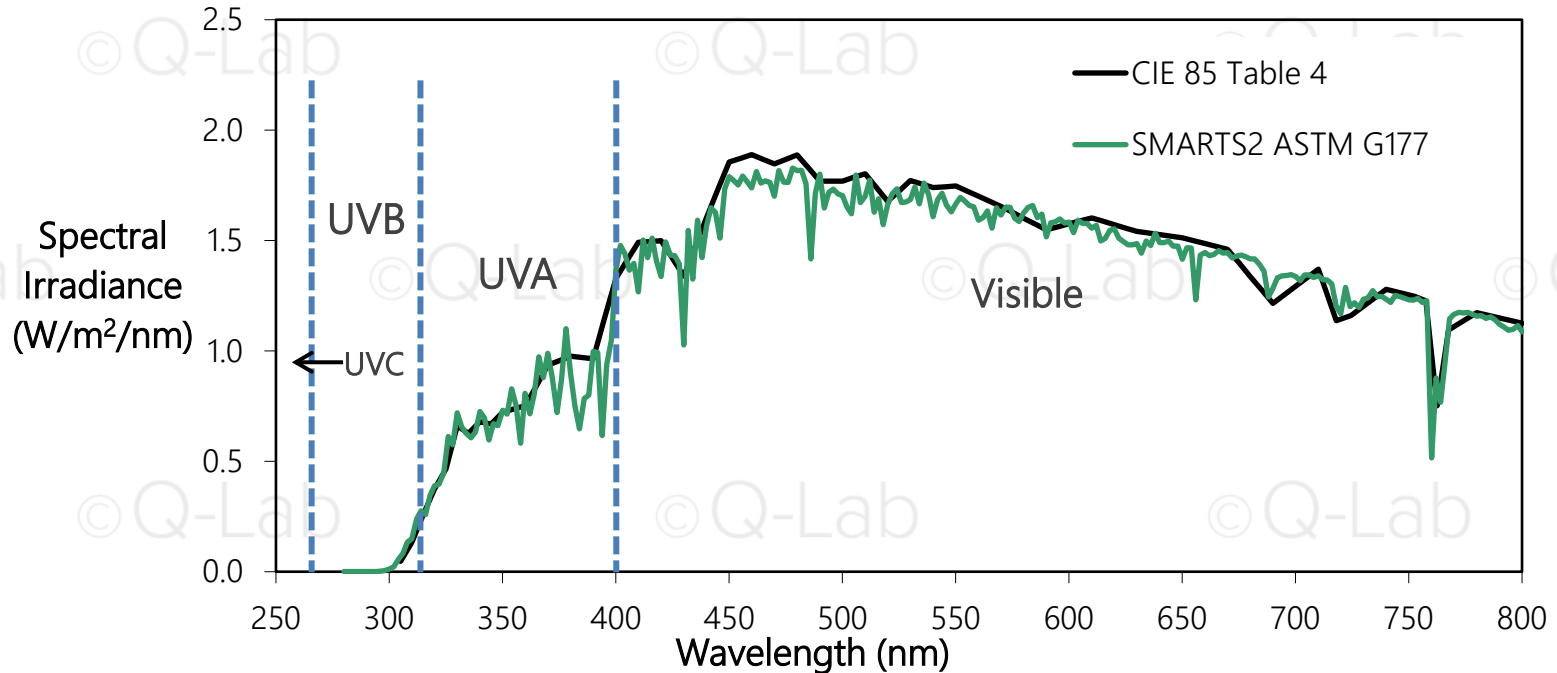
$[J/m^2]$ or $[W \cdot s/m^2]$ / $[mJ/cm^2]$ or $[mW \cdot s/cm^2]$

¹ ASTM G113 – Terminology

² ISO 9288 – Physical quantities and Definitions

Spectral Irradiance

Also called Spectral Power Distribution, or SPD



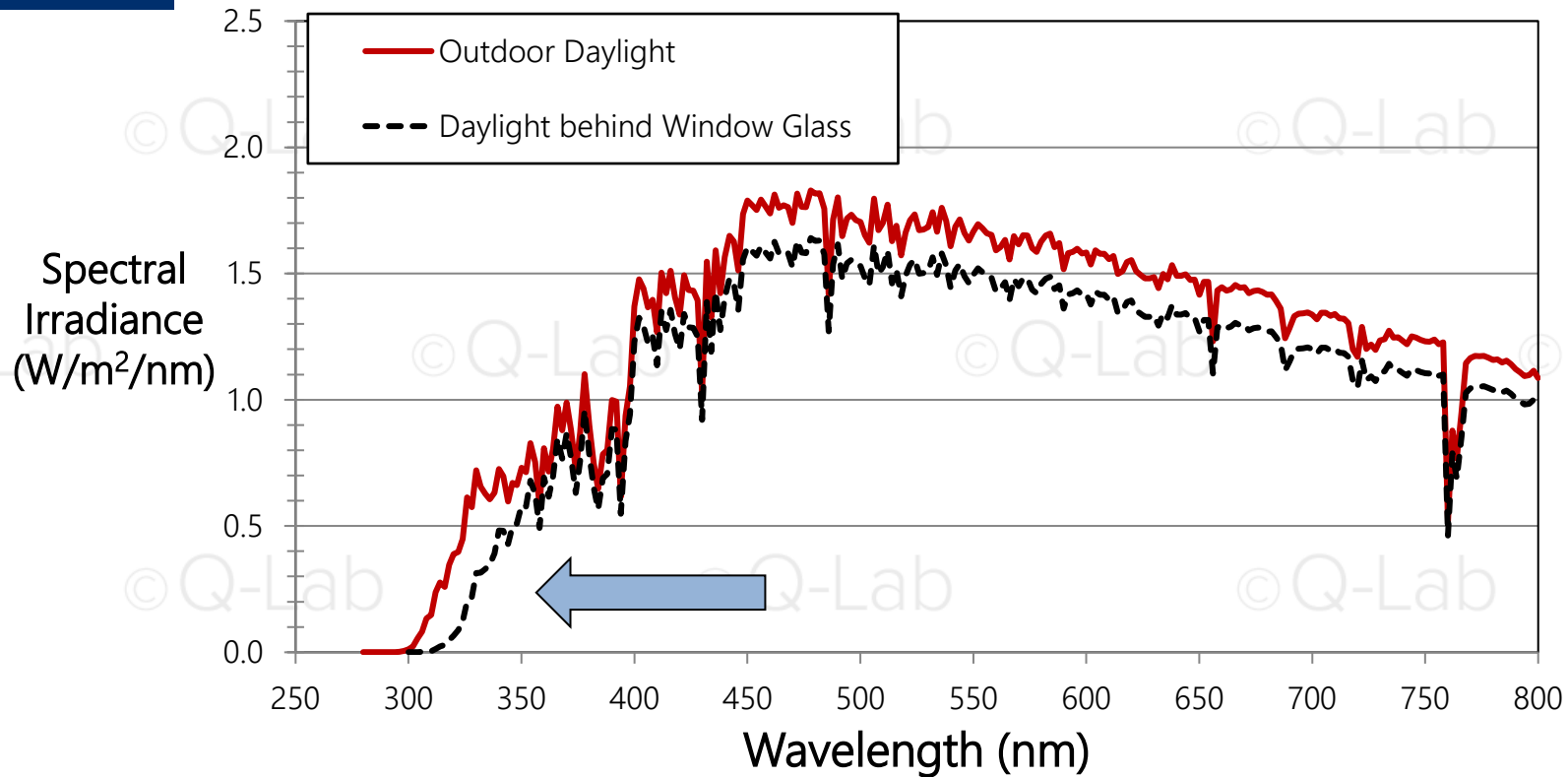
The absolute or relative radiant power emitted by a source, or incident upon a receiver as a function of wavelength. (ASTM G113)

Spectrum Modifiers

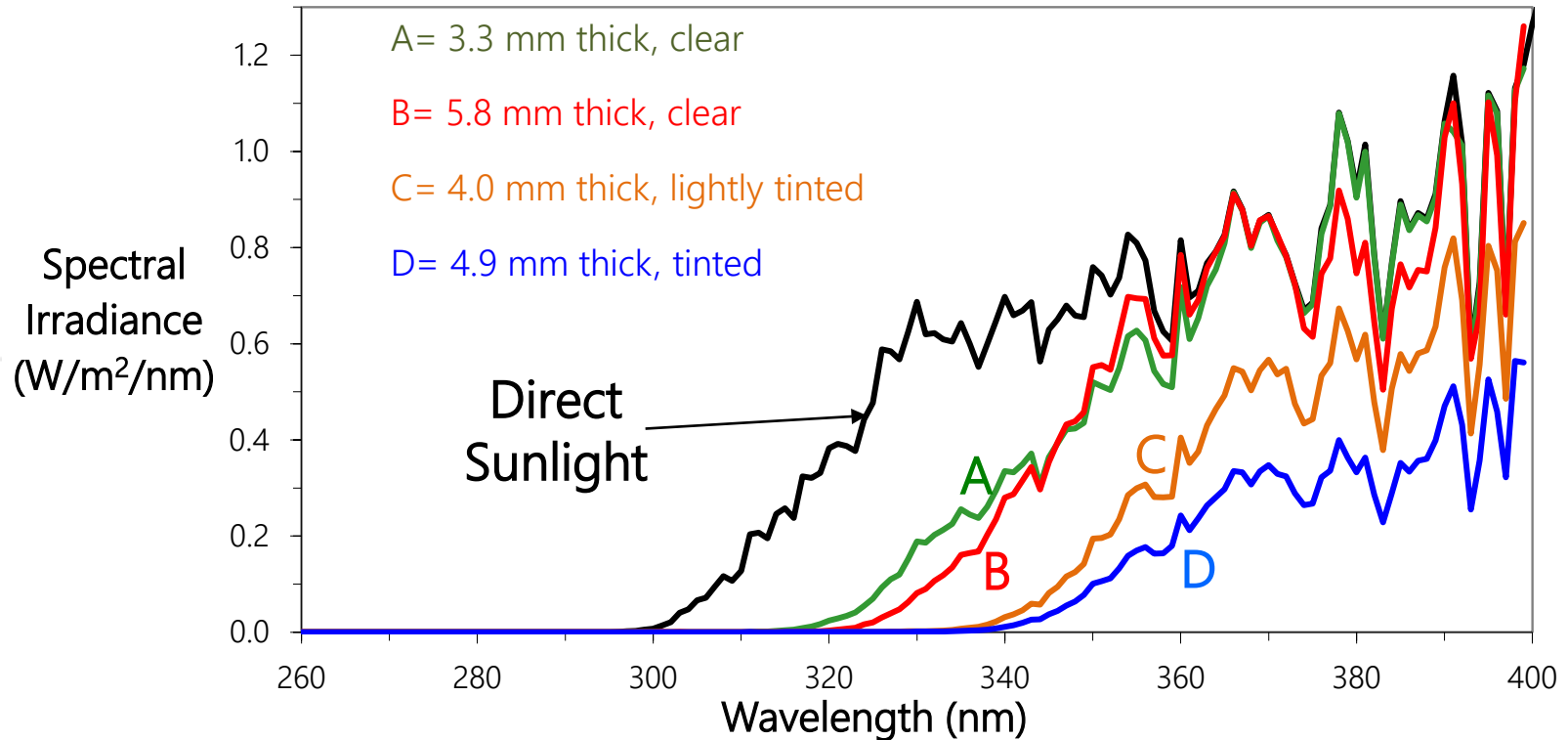


- 태양의 각도 Sun angle
 - Time of Year (e.g. summer)
 - Time of Day (e.g. noon)
 - 위도 Latitude
- 조도 Altitude

Sunlight Through Window Glass



Sunlight Through Automobile Glass



Heat Effects

- 시편의 온도 상승 Elevated specimen temperature
- 부피의 변화 Dimensional change
- 증발 Evaporation
- 열 노화 현상 Thermal aging
- 열 충격 Thermal cycling



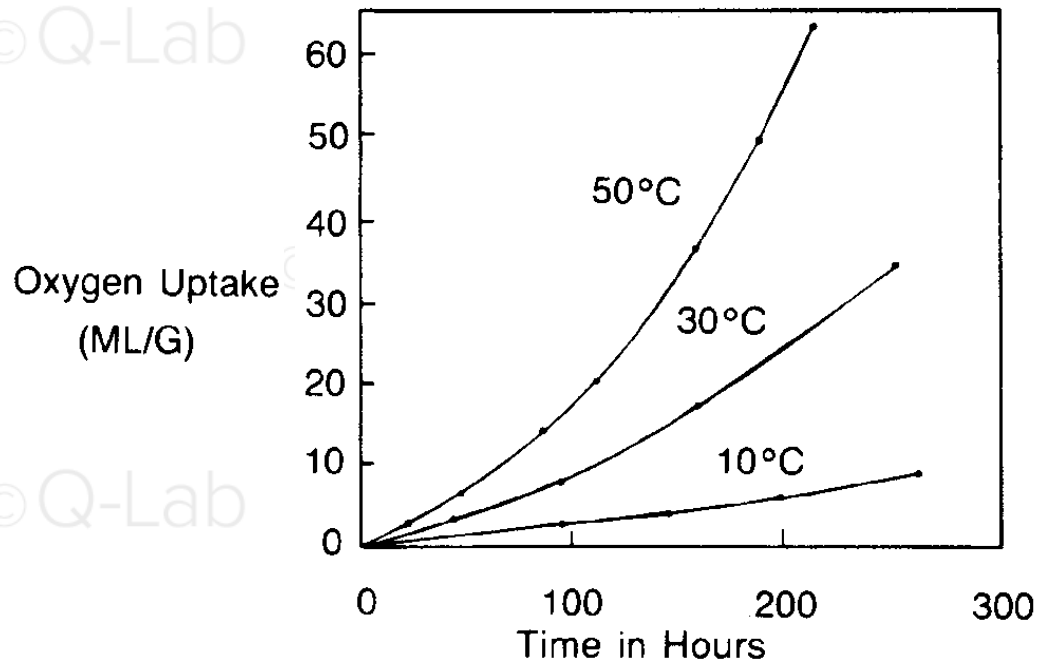
Photochemical Reactions and Heat



- 광화학 반응은 단순한 한단계가 아니다.
Photochemical reactions are **not** usually simple one-step reactions
- 주요 광화학 반응은 열 반응이 아니다.
Primary photochemical reactions *are not* affected by heat
- 열 반응은 부수적인 광화학 반응이다.
Secondary photochemical reactions *are* affected by heat

Effect of Temperature:

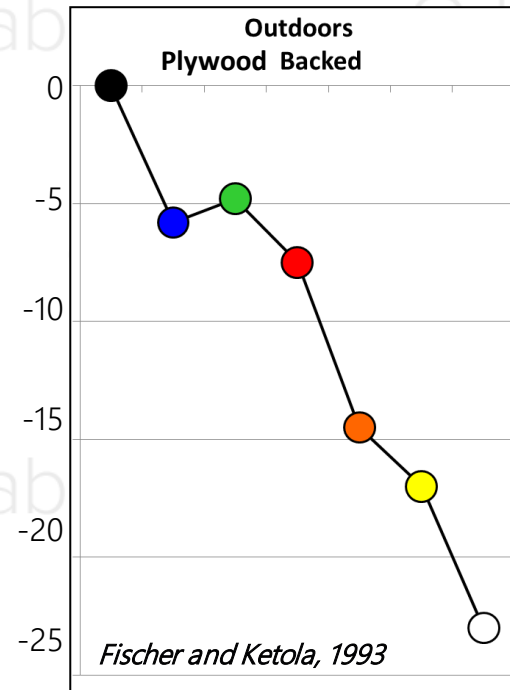
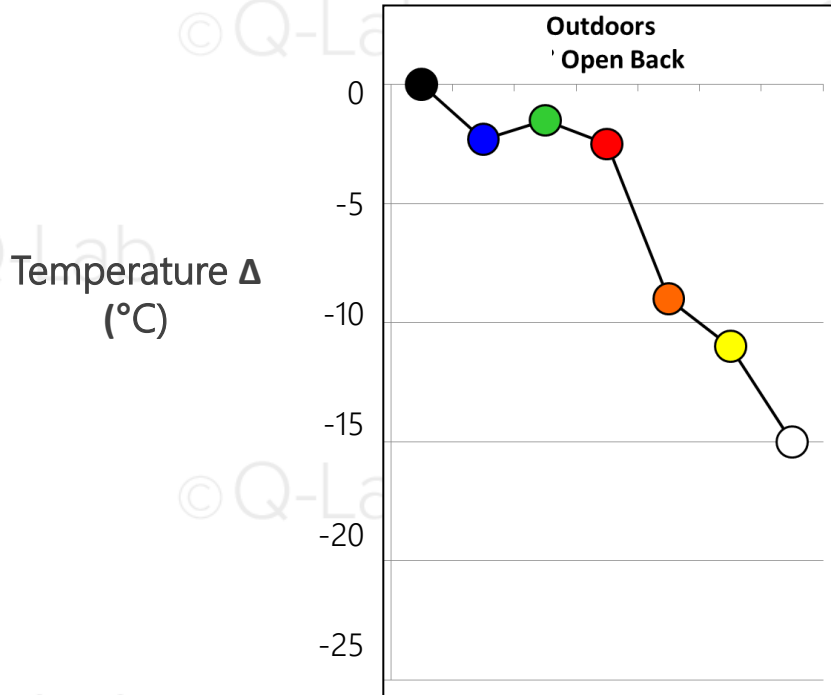
폴리에틸렌의 산화율 Oxidation Rate of Polyethylene



**Time In Hours Exposed to UV lamps*

Temperature and Color

어두운 색이 더 높은 온도를 갖는다. Darker Colors Have Higher Temperatures!



Heat behind Window Glass



유리창 뒤에 있는 자동차 내장품의 온도는 100 °C까지도 상승한다

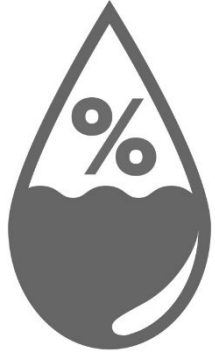
Temperature of automobile interior components behind window glass can exceed 100 °C

Water

- 화학적 반응 Chemical Reactions
 - 솔루션의 반응 Reactions in solution
 - 산소 이동량의 증가에 의한 반응 촉진 Facilitates reaction via increase in oxygen transport
- 물리적 효과 Physical Effects
 - 침식 Erosion
 - 흡수와 결빙 Absorption/freeze-thaw
 - 열 충격 Thermal shock
 - 타격 Impact (material loss)



Forms of Water



Relative Humidity
Time of Wetness



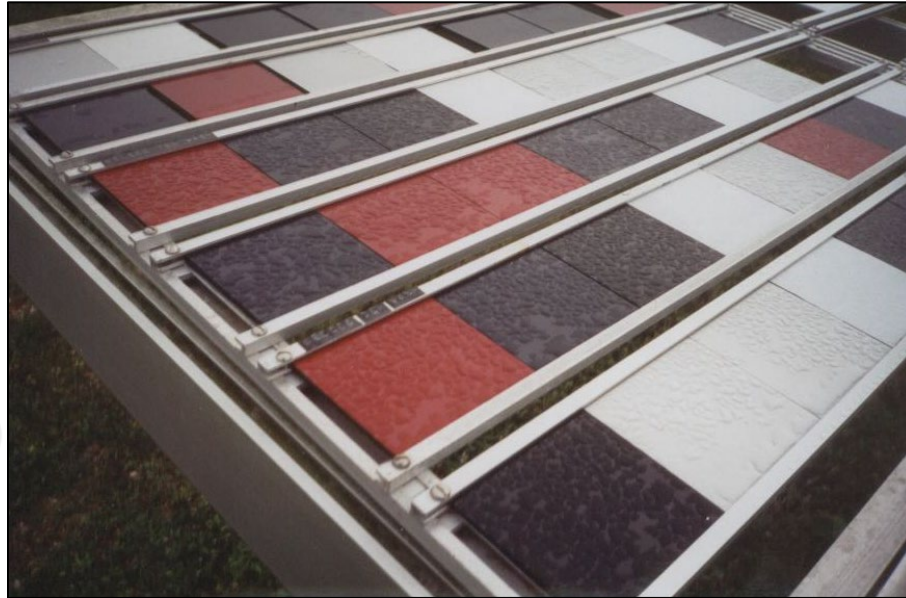
Rain
Thermal Shock and Erosion



Dew
Most Outdoor Wetness

Materials outdoors are wet longer than you think 12+ hours/day

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



Don't Underestimate the Effect of Moisture!

- 품질저하 속도의 변화 Changes the rate of degradation
- 품질저하 방식의 변화 Changes mode of degradation
- 가속의 어려움 Difficult to accelerate

Summary: Forces of Weathering

- Sunlight
 - UV는 사실상 모든 폴리머 분해의 원인이 된다 UV is most damaging for most durable materials
 - 재료 조합 및 스펙트럼의 작은 변화가 재료 품질 저하의 큰 영향을 끼칠 수 있다 Material-specific "Spectral Sensitivity" affects degradation
- Temperature
 - 햇빛 + 열 = 품질저하 속도 증가 Includes both heat and thermal cycling
 - 부수적인 반응 촉진 Influences secondary reactions
- Water
 - 이슬이 야외 습기의 근원이다 Dew is responsible for most wetness
 - 비와 습도 또한 내후성에 기여한다 Rainfall and humidity also contribute to weathering

Weathering includes synergistic effects between these factors!

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Why Test?

- 기술 규격 대응 Meet specifications
- 예측 못한 재해 방지 Avoid catastrophes
- 신뢰도 고양 Enhance your reputation
- 품질 불량 건 검증 Verify supplier claims
- 제품 내구성 향상 Improve product durability
- 원자재 비용 절감 Save on material costs
- 제품의 활용도 확대 Expand existing product lines
- 새로운 시장 진입 Enter new markets
- 경쟁 우위 확보 Outrun the competition
- 규제보다 앞선 행보 Stay ahead of regulations

Laboratory Testing is a Tool for Directional Decision-Making

Laboratory Accelerated tests can help you:

- 더 좋은 결정 혹은 더 빠른 결정 Make decisions better and/or faster.
- 나쁜 결정을 할 수 있는 위험 감소 Reduce risk of making bad decisions
- 느린 결정을 할 수 있는 위험 감소 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">• Defined• Short	Material specification

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Correlative	Rank-ordered data	<ul style="list-style-type: none">• Open-ended• Medium	Natural exposure (Benchmark site)
Predictive	Service life Acceleration factor	<ul style="list-style-type: none">• Open-ended• Long	Natural exposure (Service environment)

Advantages of Accelerated Lab Testing

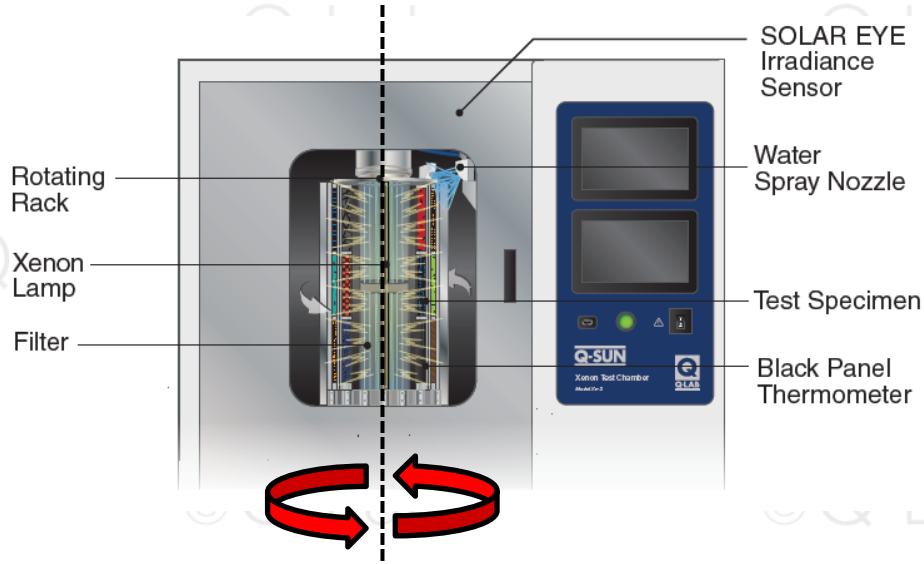
- Fast
 - Repeatable
 - In-house
-
- Great for Quality Control, Qualification, and Research & Development

What We Will Talk About

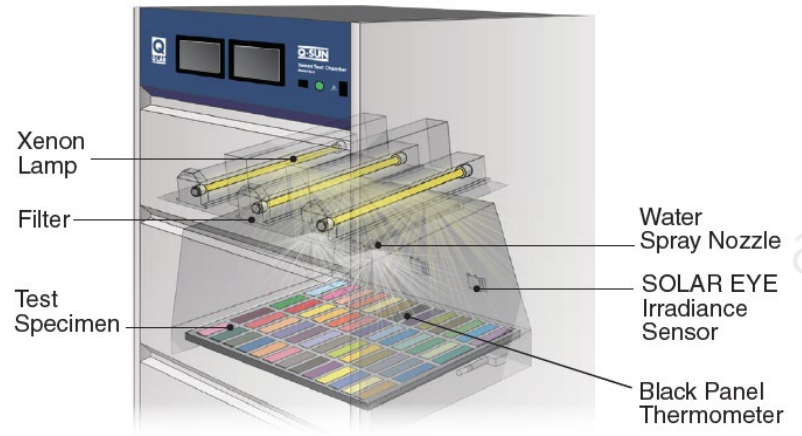
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Xenon Arc Laboratory Weathering

Xenon Arc Test Chamber



Rotating Rack



Flat Array

Xenon Arc Lamps

Air-cooled



Water-cooled



Water-cooled
Assembly



Xenon Arc Spectra

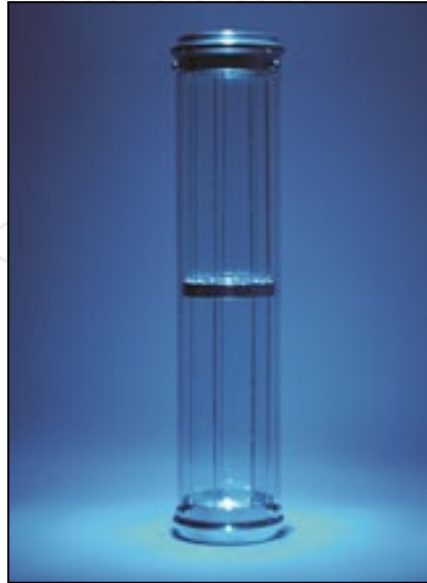
Major Influencing Factors

- **옵티컬 UV 필터** Optical filters
- **조도 수준** Irradiance level (intensity)
- **컨트롤 포인트** Wavelength at which irradiance is controlled (“control point”)
- **램프 노화** Lamp aging

Overview of Filters

- Daylight
- Window
- Extended UV

Rotating drum "lantern"

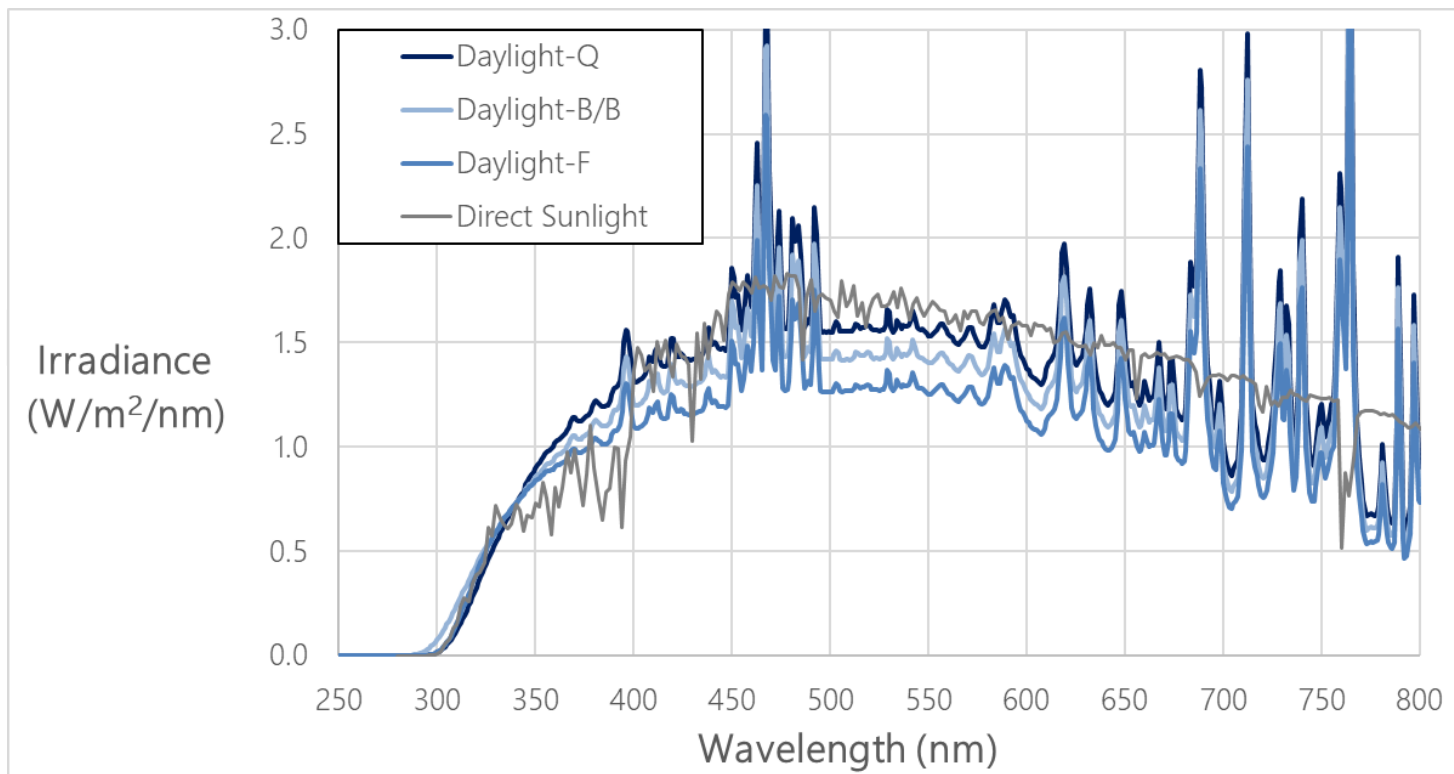


Flat array filter

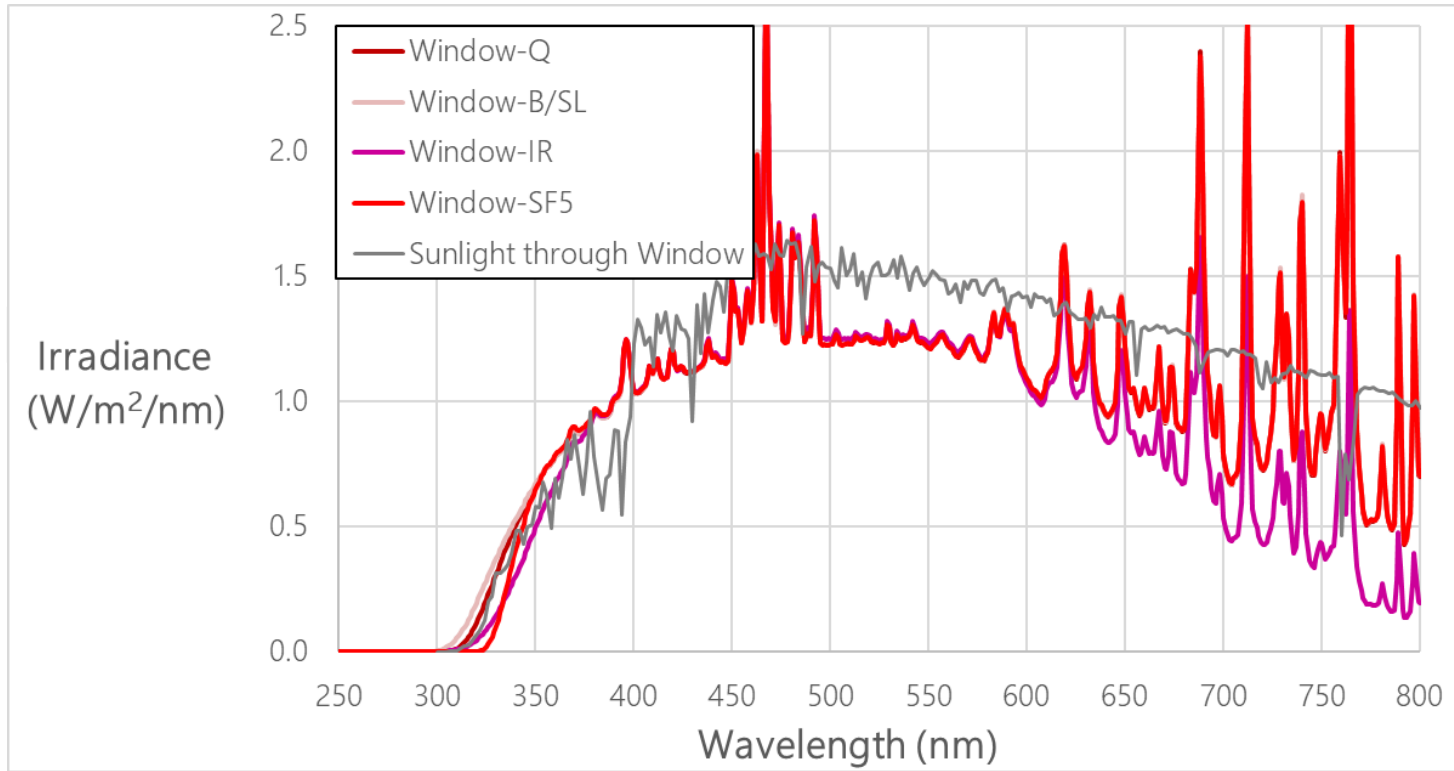


**Other specialized filters used occasionally*

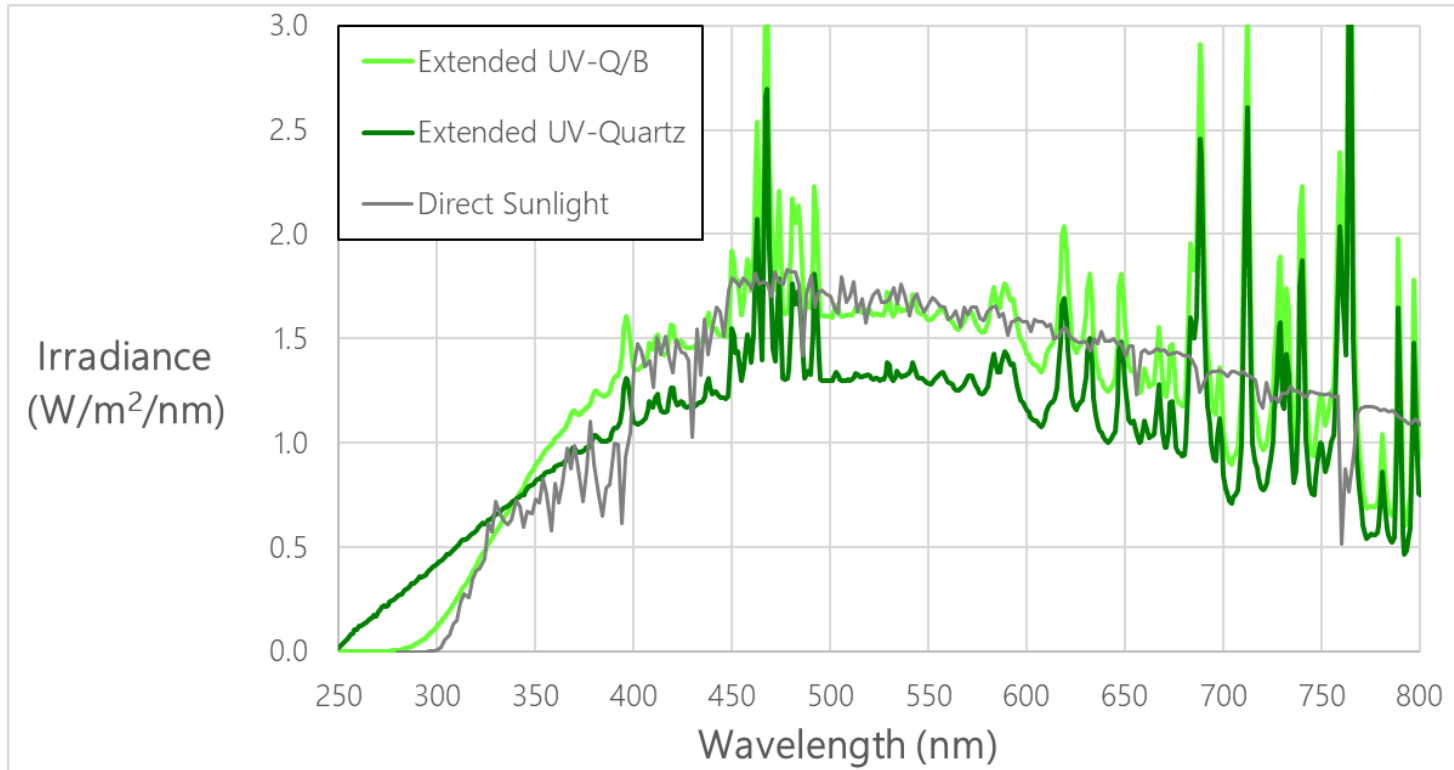
Daylight Filter Comparison



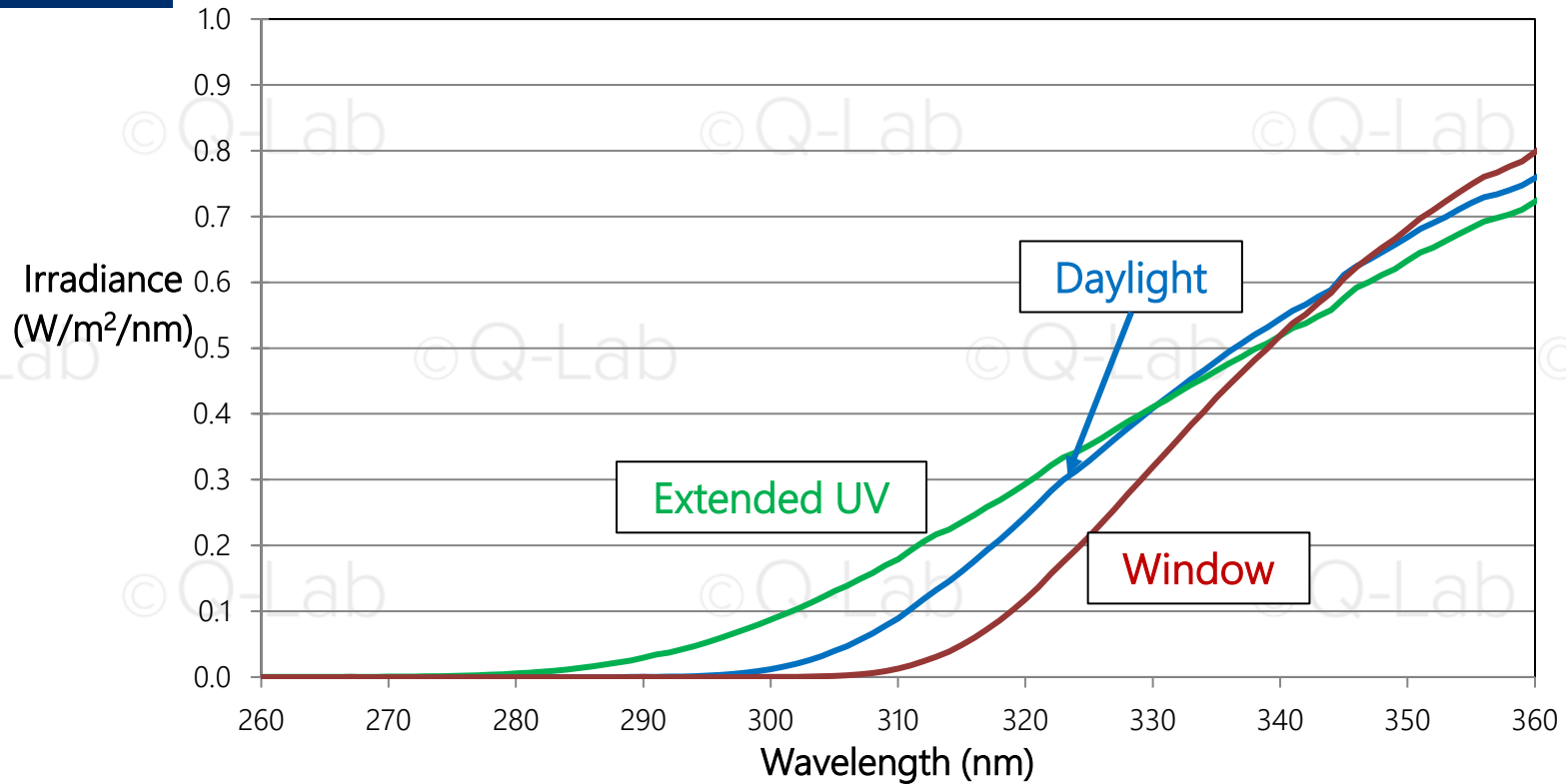
Window Filter Comparison



Extended UV Filter Comparison



Optical Filters: UV Region



Optical Filter Aging

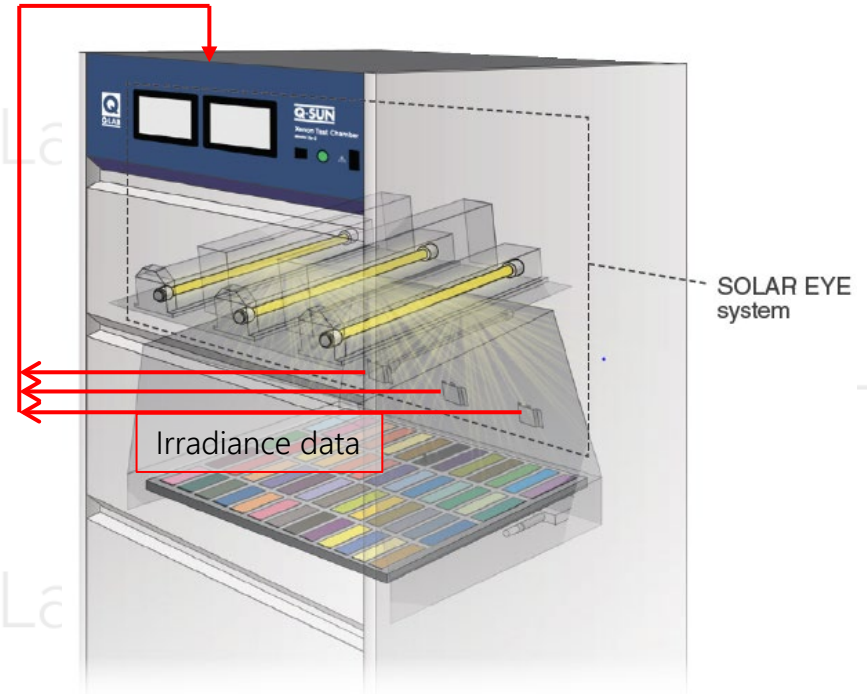
Water-Cooled vs Air-Cooled

- 수냉식 램프의 필터는 매 400~2000 시간마다 교체가 필요하다
Filters for water-cooled lamp systems need to be replaced every 400-2000 hours
 - 초 순수에서도 오염물질로 인해 필터 투과율이 감소한다
Contaminants, even in ultra-pure de-ionized water, reduce filter transmittance over time
- 모든 공냉식 램프의 필터는 노화되지 않고 교체가 필요하지 않다
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
 - 단파장 영역의 광열화 Shorter wavelengths cause more photodegradation
 - 제논 램프의 노화 Fails to account for xenon lamp aging

Why Is Choice of Control Point Important?

- 사용에 따른 제논 램프의 노화 Xenon Arc lamps age with use
- 스펙트럼의 이동은 램프 수명을 제한한다 Spectral shift
limits useful lamp life
- 관심 있는 파장대의 조도를 컨트롤 하여 반복성과 재현성 극대화 Controlling irradiance in wavelength region of interest maximizes repeatability and reproducibility

Black Panel Temperature Control

- 가장 흔하게 사용 Most common in test standards
- 시편 표면 최대 온도의 근사값 Approximates maximum specimen surface temperature
- 챔버 에어 온도와 조합하여 사용할 수 있음. 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 pen-like probe with a silver tip. A blue pen with the Q-Lab logo and 'q-lab.com' is placed next to it for scale. A silver adjustment knob is visible on the left side.	Black painted stainless steel	Uninsulated Black Panel	Black Panel
 A photograph of an insulated black panel temperature sensor. It features a black panel mounted on a white PVDF base. A blue pen with the Q-Lab logo and 'q-lab.com' is placed next to it for scale. A silver adjustment knob is visible on the left side.	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,

가속을 최대화 하기 위해 최대 온도 사용 use maximum service temperature

오류를 최소화 하기 위해, 최대 온도를 초과해선 안된다. To minimize error, *DO NOT* exceed maximum service temperature

Chamber Air Temperature Control

- 특정 시험 규격에서 요구됨. Required by certain test methods
- 상대 습도 제어를 위해 필요함. Necessary for control of relative humidity (RH)
- 센서가 빛으로부터 보호 Sensor must be shielded from light
- 블랙패널 온도는 복사열을 흡수하여 항상 챔버에어 온도보다 높다. BP temp always hotter than chamber air temp from absorbing radiant heat

Relative Humidity Control

- 많은 시험 규격에서 요구 Required by many test methods
 - Textiles
 - Automotive
- 많은 제논 시험기는 상대습도 제어 가능 Many xenon testers can generate and control relative humidity
 - Boiler system
 - Nebulizer system
 - Air atomizing nozzle
- 많은 내구성 재료에서 RH 는 워터 스프레이와 컨덴세이션과 비교하여 차이가 거의 없다. For many durable materials, RH makes very little difference compared to spray and condensation

Xenon Arc Water Spray

Front spray

- 수분 공급의 주요 방법 Primary method of water delivery
- 검교정 기술이 최근 개발 됨. Calibration technique for front spray recently developed (ASTM D7869)

Back spray

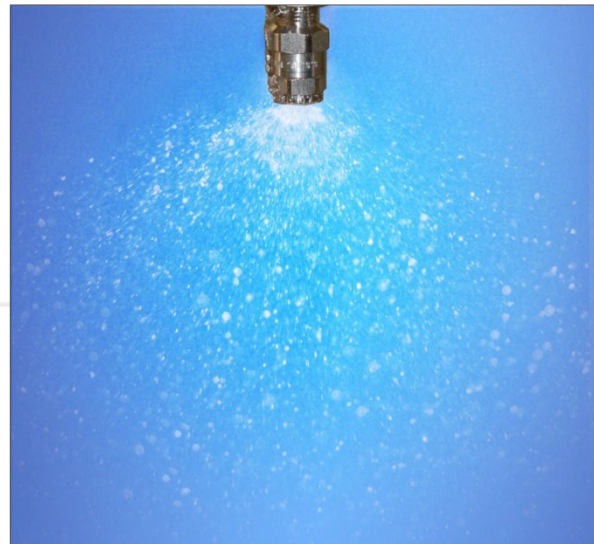
- 응축 발생을 의도한 방법이지만 결과적으로 실패. 일부 표준에서 유지함. Result of a failed experiment intended to generate condensation; persists in some standards

Dual spray

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

Immersion (Ponding)

- 일부 표준에서 제시된 전면 스프레이의 대안. Alternative to front spray called out in some standards



Xenon Arc Summary

- 태양광 전체 스펙트럼에 대한 최고의 재현 Best simulation of full-spectrum sunlight
- 램프 노화 Lamps experience aging (fulcrum effect)
- 온도 효과 Temperature effects
- 워터 스프레이와 상대습도 Water spray and RH control
- 형광 UV 시험기에 비해 추가 비용 발생 및 유지보수 복잡. Additional cost, maintenance, and complexity compared to fluorescent UV testers

Q-SUN Xenon Arc Testers

Xe-3



Xe-1



Xe-2

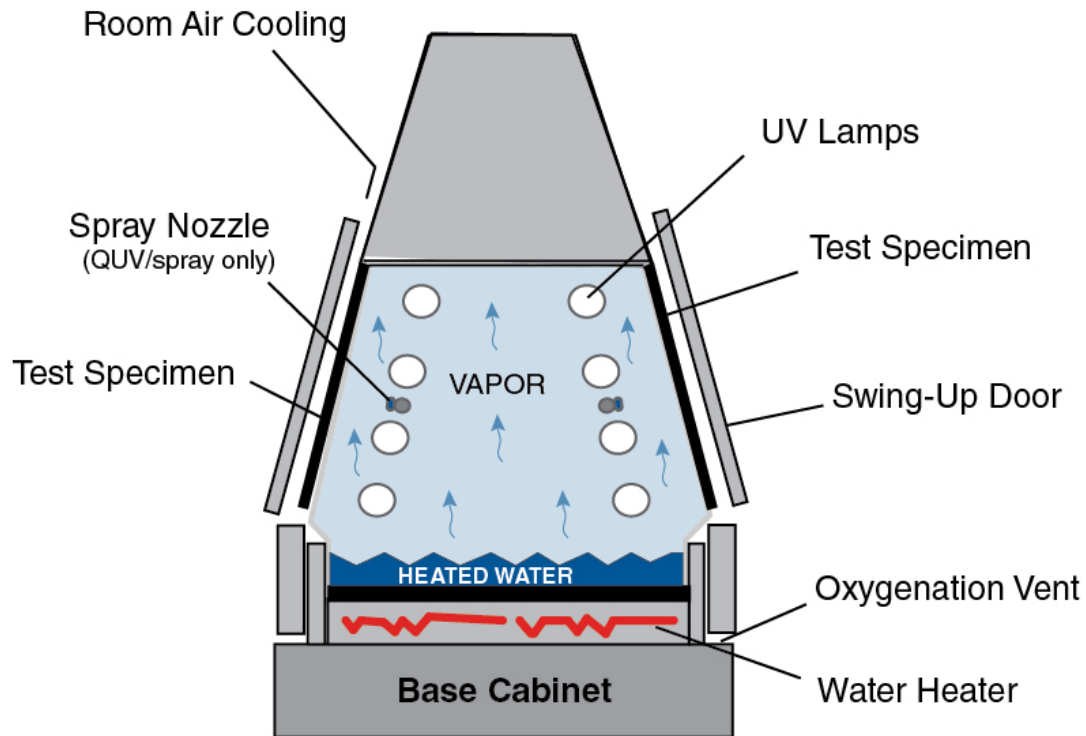


Xe-8



Fluorescent UV Laboratory Weathering

Fluorescent UV Schematic

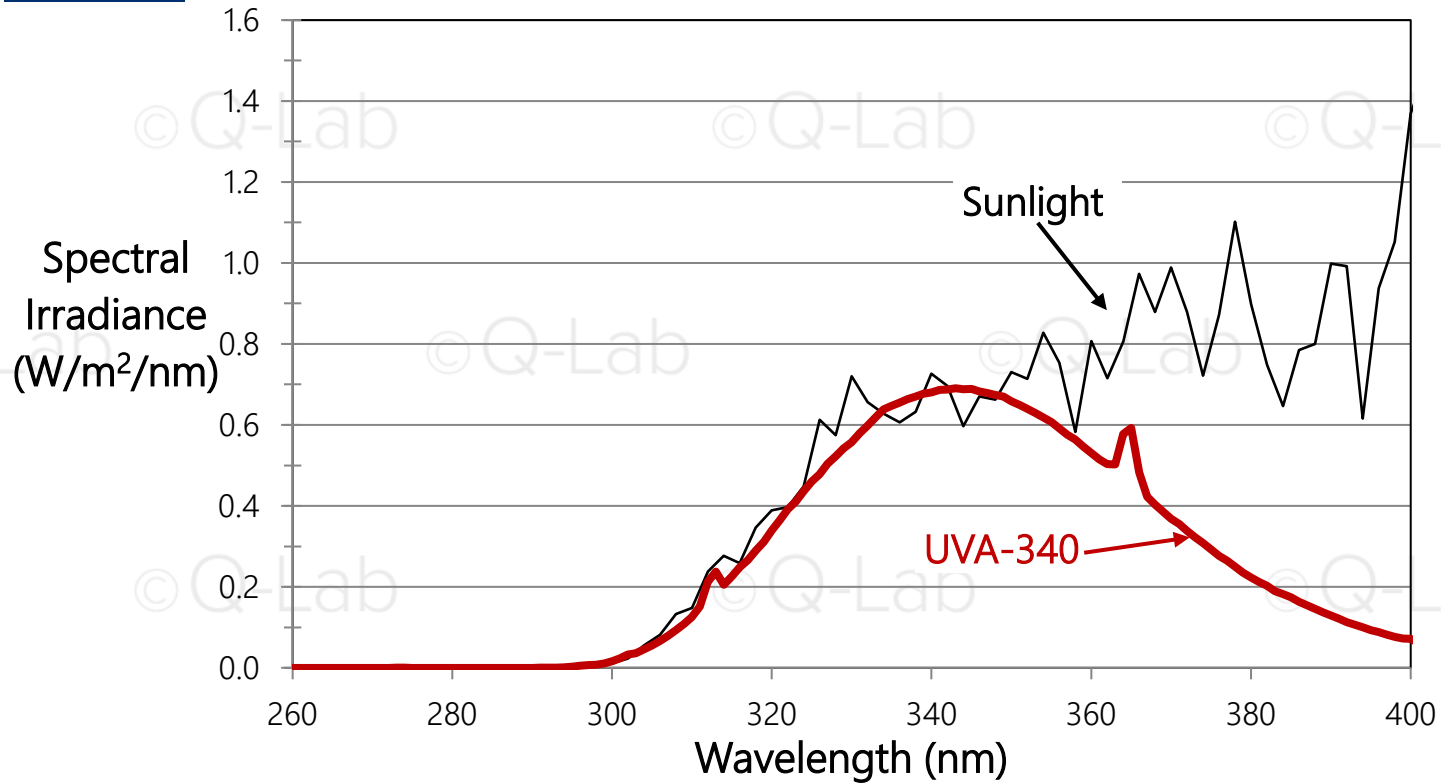


Fluorescent UV Lamps

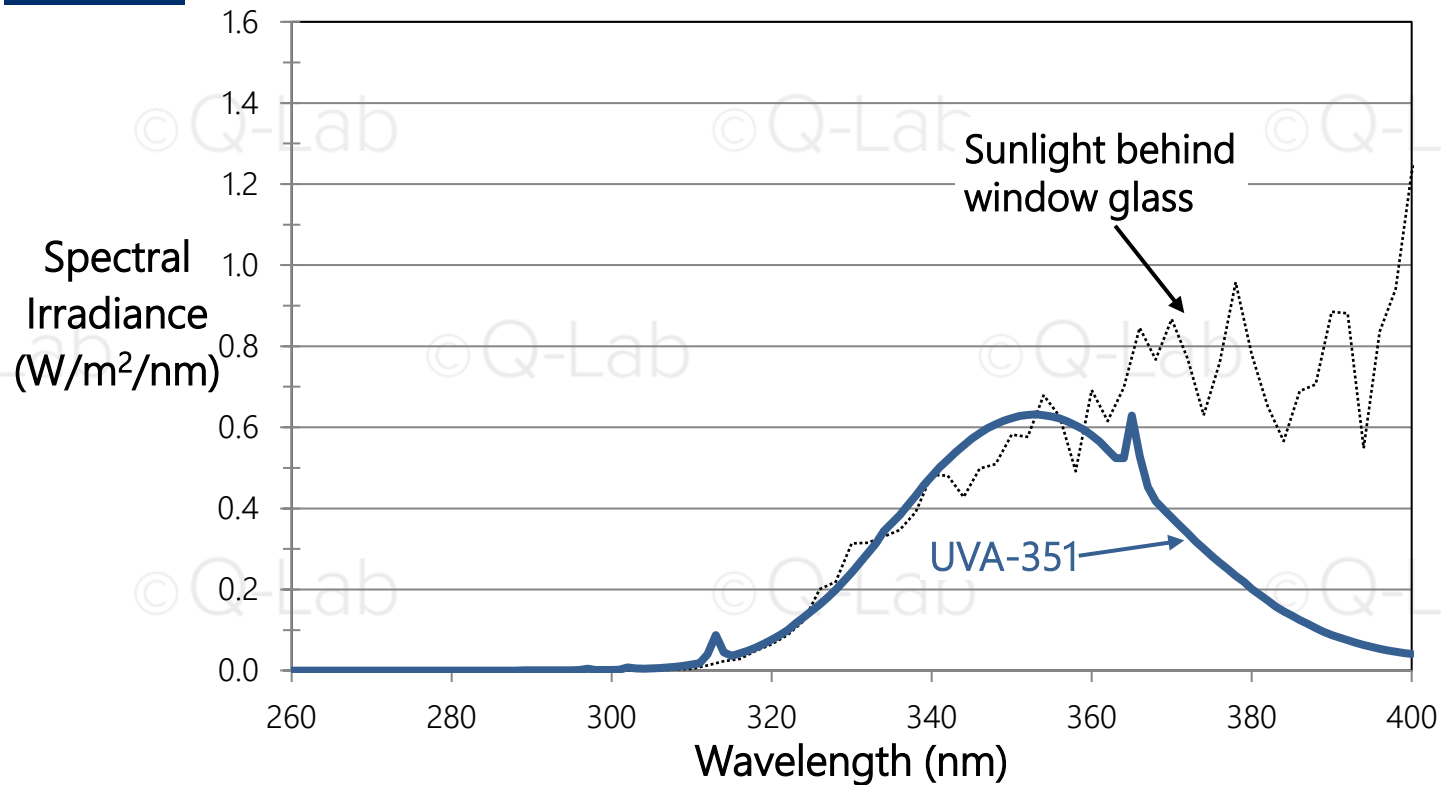
- UVA-340 (Daylight UV)
- UVA-351 (Window UV)
- UVB-313EL (Extended UV)
- UVC-254 (UVGI)
- TUV-421
- Cool White (Indoor, office)



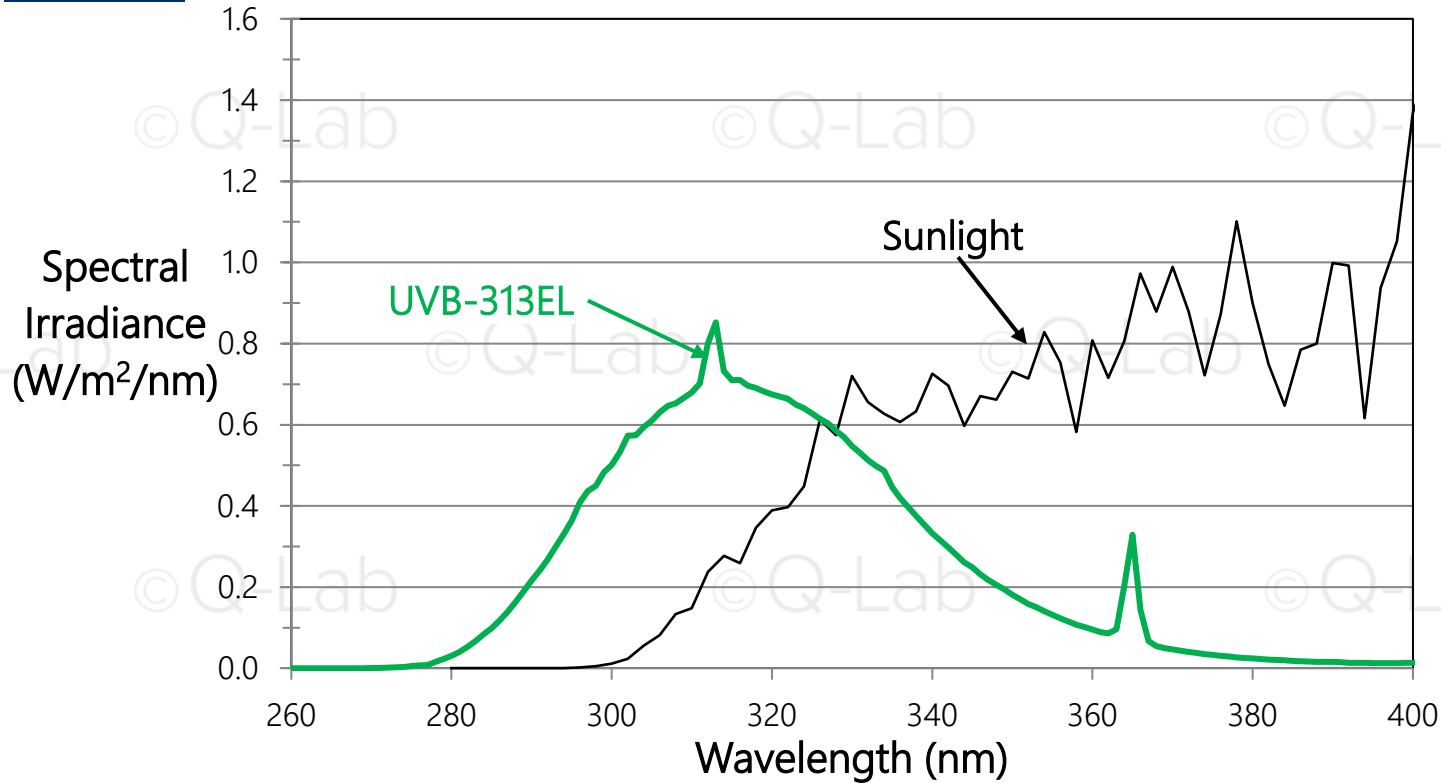
UVA-340 Lamps



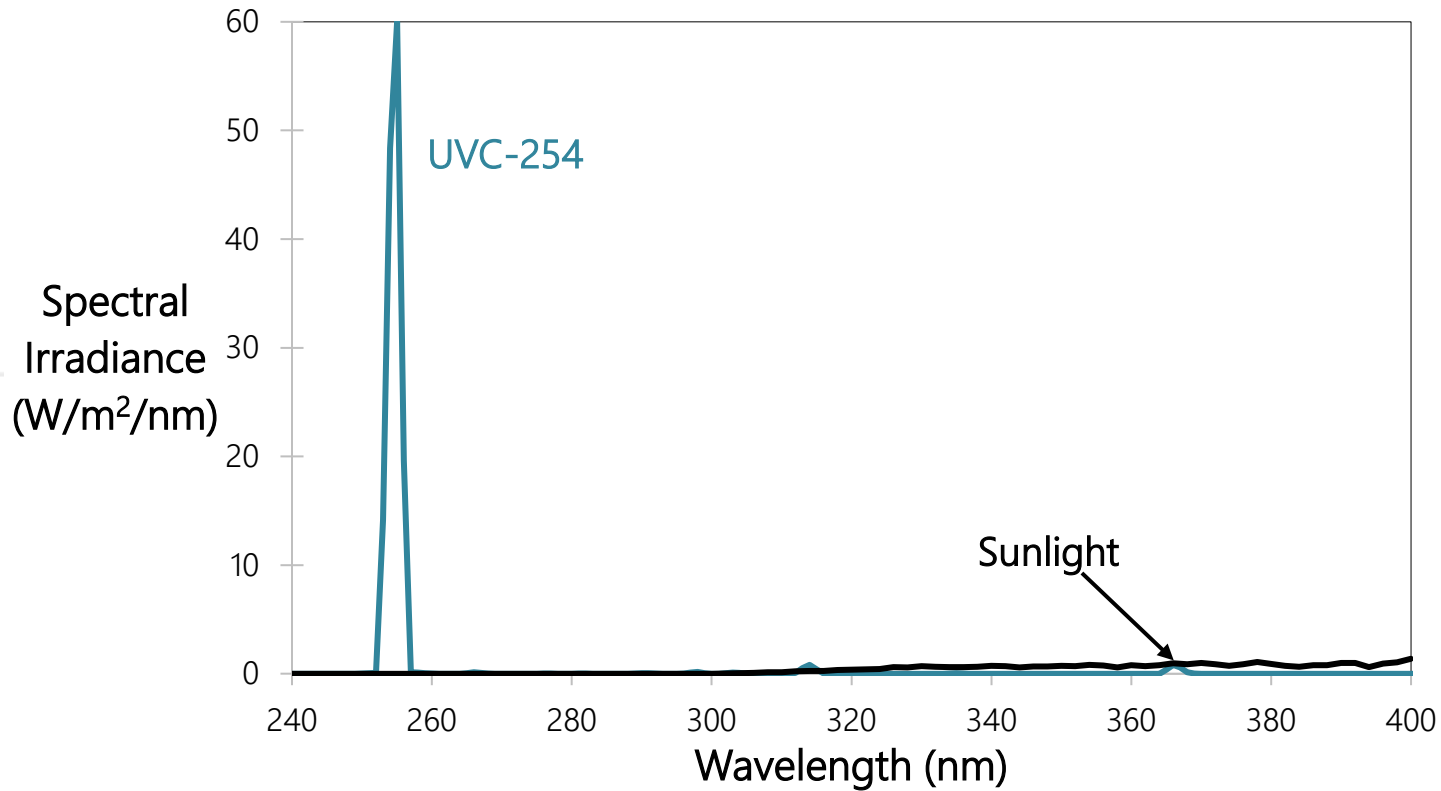
UVA-351 Lamps



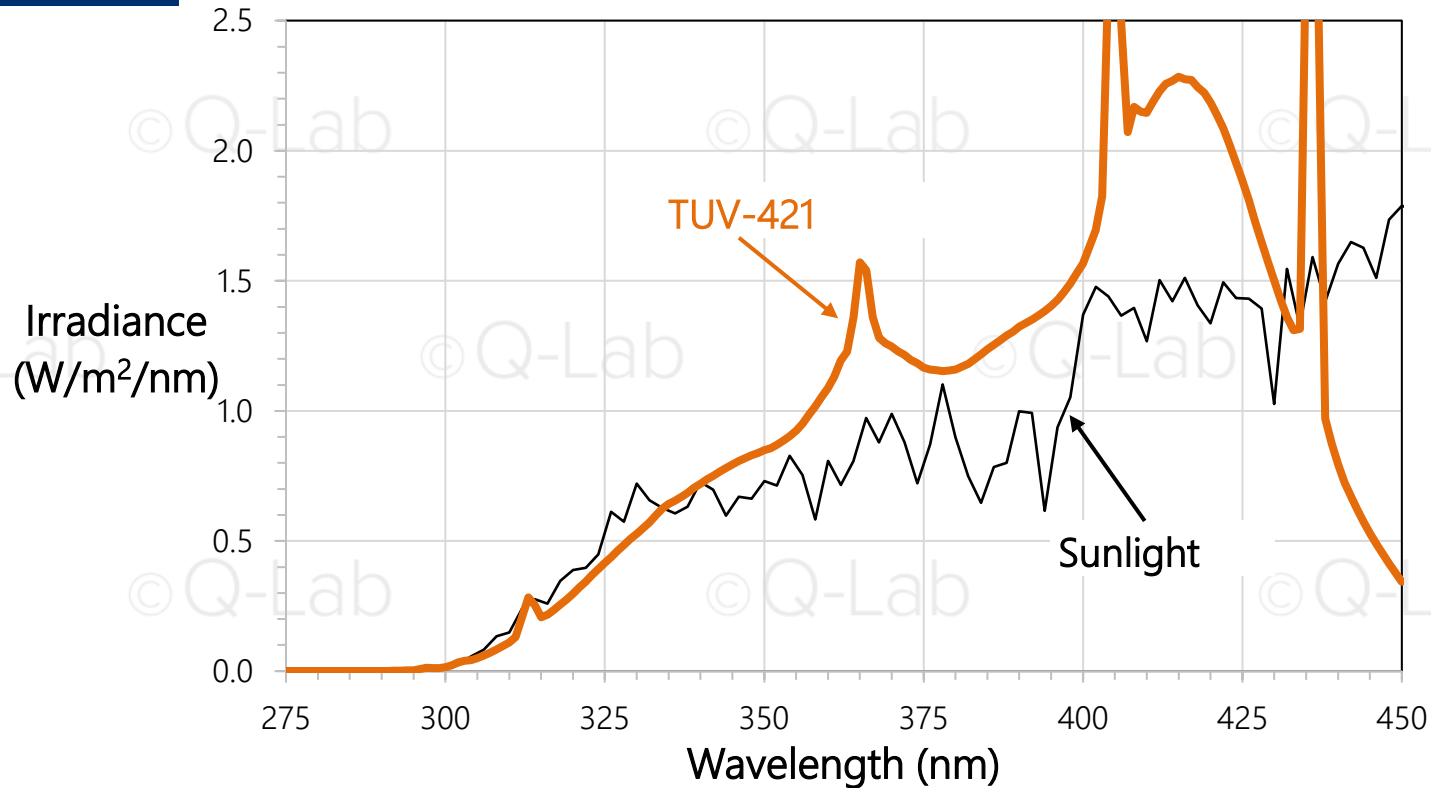
UVB Lamps



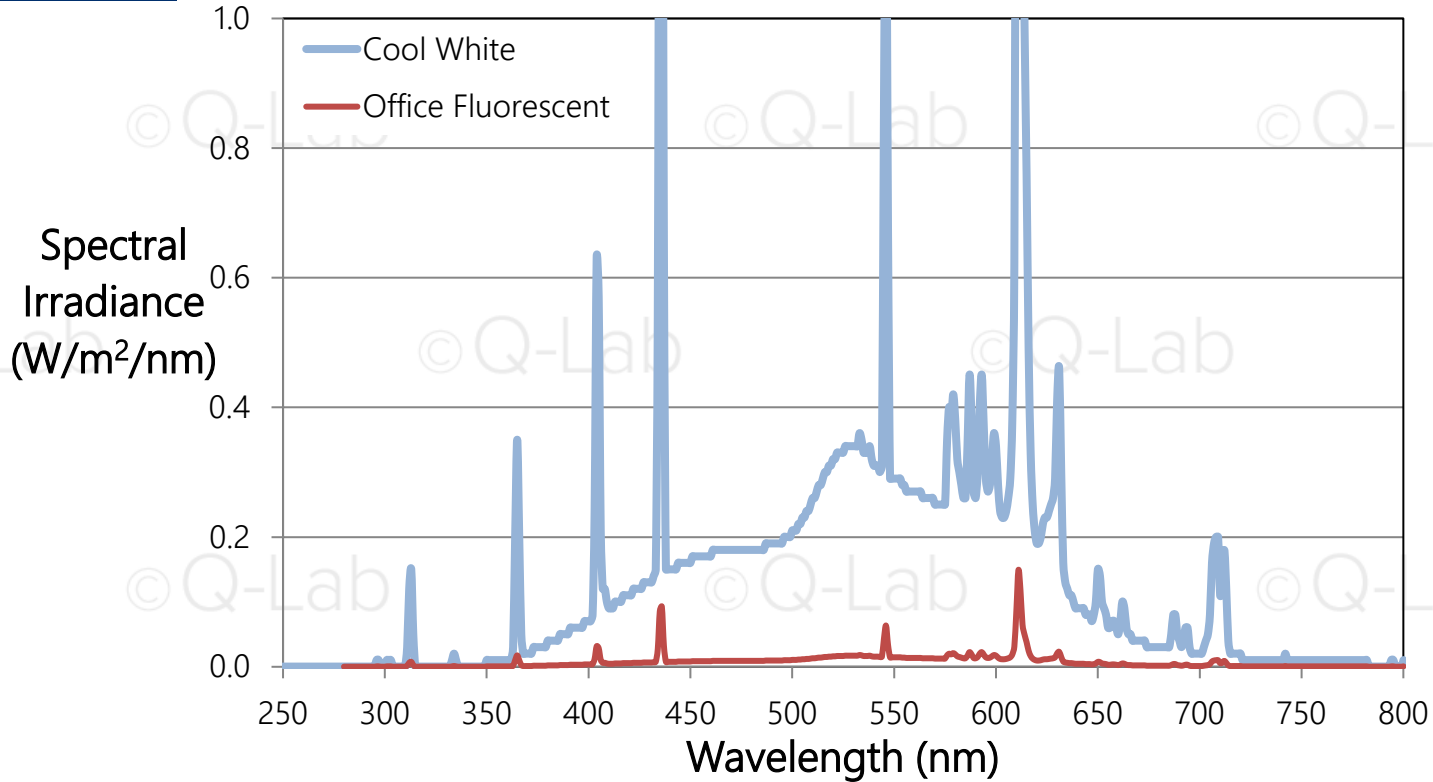
UVC Lamps



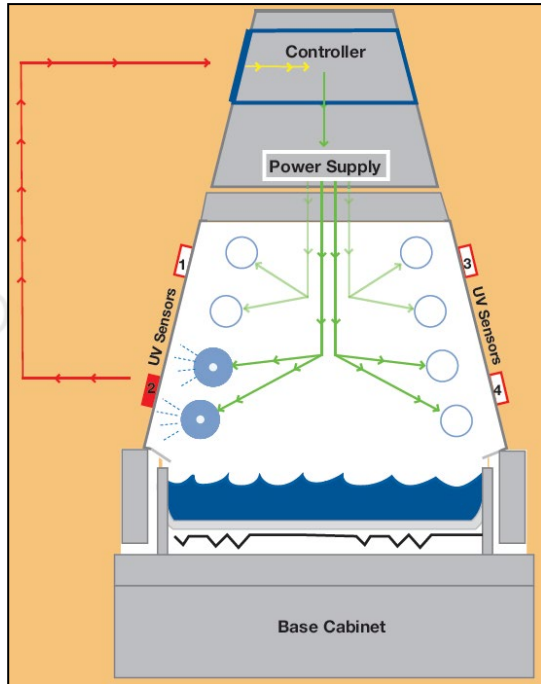
TUV-421 Lamps



Cool White Lamps



QUV SOLAR EYE™ Irradiance Control



Feedback Loop Control

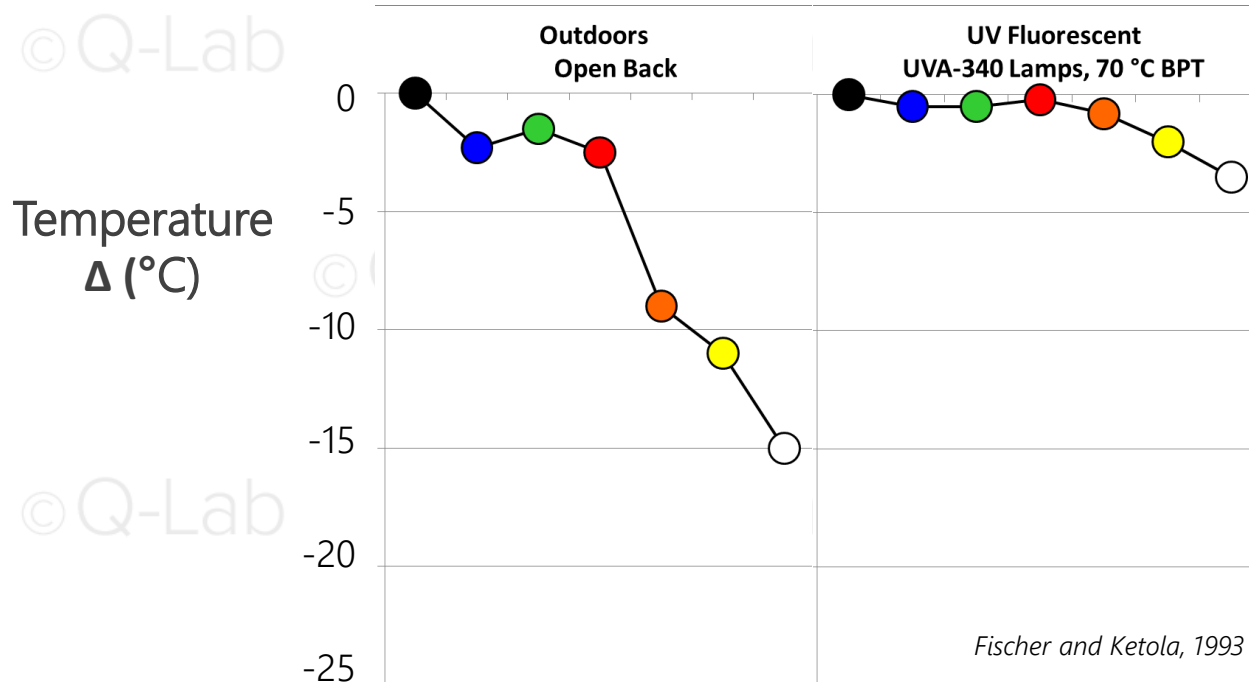
- Fluorescent UV lamp
- Light sensor
- Control module

Fluorescent Lamp Advantages

- 빠른 결과 Fast Results
- 간편한 조도 제어 Simplified irradiance control
- 안정적인 스펙트럼, 노화 없음. Very stable spectrum – no aging
- 유지보수 간편. Low maintenance
 - 간편한 검교정 Simple calibration
- 낮은 가격과 운영비용 Low price and operating cost
- 간단하고 쉬운 유지보수 Simple and easy to maintain

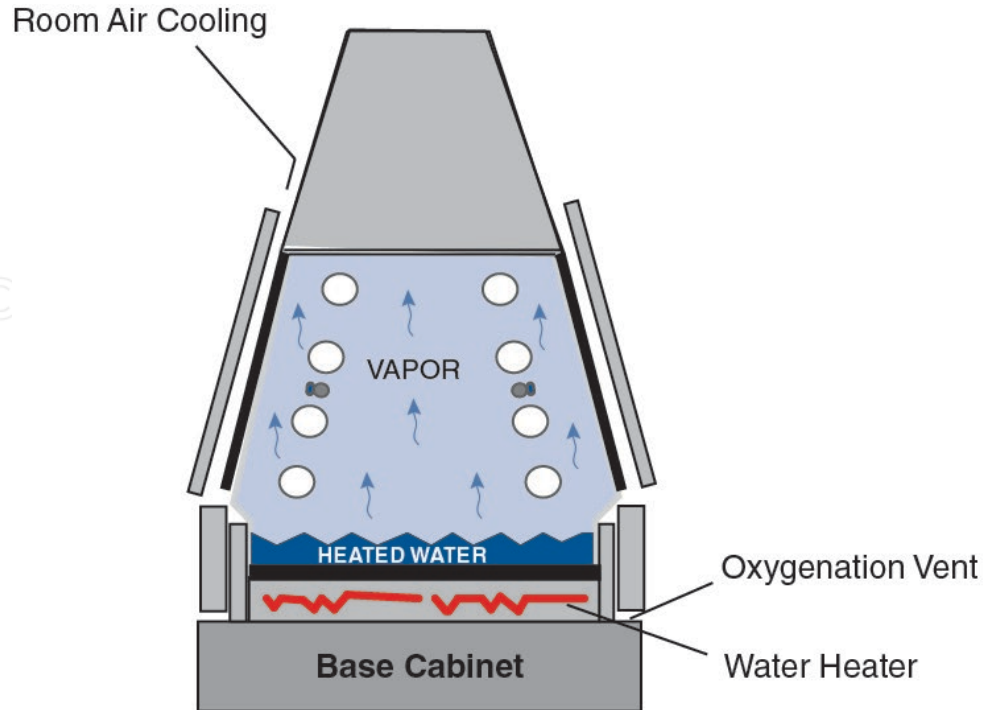
Temperature & Color

Temperature difference between colored panels and Black Panel



Fischer and Ketola, 1993

Condensation



Condensation Advantages

- 자연 습기와 가장 매칭 Closest match to natural wetness
- 실험실 시험에서 습기를 가속화 하는 가장 좋은 방법 Best way to accelerate water in a laboratory tester
- 온도의 상승 Elevated temperature
- 높은 산소 함량 High O₂ content
- 증류를 수행함. 깨끗한 물을 시편에 공급 Tester performs distilling – you cannot deposit debris on specimens! Water is guaranteed to be clean.



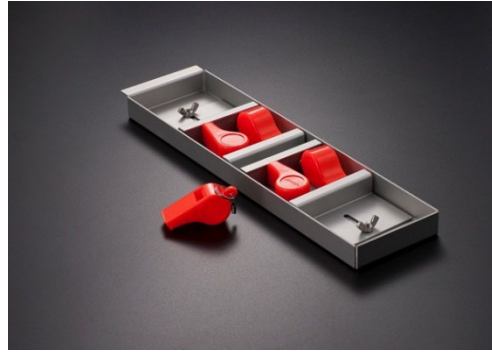
Creating condensation in the QUV is easy and does not require expensive, pure water

Water Spray

- 시편을 완전히 적셔줌. Ensures that parts get fully saturated
- 침식 및 열 충격 생성. Creates erosion & thermal shock
- 응축보다는 사용 빈도 적음. Less common than condensation



QUV Specimen Mounting



Fluorescent UV Summary

- UVA-340 단파장 UV 최고의 재현. UVA-340 best simulation of short-wave UV
- UVB-313 가장 빠르고 가혹한 조건 UVB-313 fastest & most severe
- TUV-421 칼라 변화를 위한 더 넓은 파장대 제공 TUV-421 offers a broader spectrum for color fade
- 안정적인 스펙트럼, 노화 없음. Stable spectrum – no aging
- 가시광선 없음. No visible light
- 현실적인 응축 Condensation realistic & rigorous
- 워터 스프레이 가능, RH 제어 불가 Water spray available but not RH control

QUV Accelerated Weathering Tester



Fluorescent UV and Xenon Arc

상호 보완적 Complementary Technologies

Fluorescent UV

- UVVA-340 단파장 UV 최고의 재현
UVA-340 best simulation of shortwave UV
- UVB-313 가혹 조건 UVB-313 might be too severe
- TUV-421 일부 가시광선 제공 TUV-421 lamps offer some visible
- 안정적인 스펙트럼 Stable spectrum
- RH 제어 불가 No RH control
- 응축 혹은 워터 스프레이 Condensation or water spray
- 저렴하고 사용이 간편함. Inexpensive, simple to use

Xenon Arc

- 풀 스펙트럼. Full spectrum (UV-Vis-IR)
- 상대적으로 장파장의 UV 와 가시광선의 최선의 재현
Best simulation of long wave UV & visible light
- 스펙트럼의 변화 Spectrum shifts
- RH 제어 RH control
- 워터 스프레이 Water spray
- 더 복잡한 시스템 More complex system

What We Will Talk About

- **내후성의 기초** Basics of Weathering
- **내후성 실험을 하는 이유** Why Perform Laboratory Weathering?
- **내후성 실험** Laboratory Weathering Testing
 - Xenon
 - Fluorescent UV
- **효과적인 테스트 프로그램의 요소** Elements of an Effective Testing Program

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">• Defined• Short	Material specification
Qualification / validation	Pass / fail	<ul style="list-style-type: none">• Defined• Medium-long	Reference material or specification
Correlative	Rank-ordered data	<ul style="list-style-type: none">• Open-ended• Medium	Natural exposure (Benchmark site)
Predictive	Service life Acceleration factor	<ul style="list-style-type: none">• Open-ended• Long	Natural exposure (Service environment)

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">• Defined• Short	Material specification
Qualification / validation	Pass / fail	<ul style="list-style-type: none">• Defined• Medium-long	Reference material or specification
Correlative	Rank-ordered data	<ul style="list-style-type: none">• Open-ended• Medium	Natural exposure (Benchmark site)

Putting It All Together

- 어떤 프로세서의 촉진시험을 할 것인지 검증 필요. Identify the kind of accelerated test
 - 옥외폭로시험 데이터는 상호 연관성 및 내구 수명 예측의 필수적 사항 Outdoor data is imperative to correlative and predictive testing
- 제품의 사용 환경 점검 Identify service environment
 - Indoor or Outdoor
 - Wet or Dry
 - Hot or Cool

Putting It All Together

- 최선의 시험 수행 Use Best Practices
 - 결과가 나올 때 까지 시험 지속 Run until a defined failure mode
 - 동일 시편 복제품 사용 Use multiple replicates
 - 평가 실시 및 위치 재조정 Perform evaluations and reposition frequently
- 최선, 최적의 시험법 구축 Pick an appropriate Test Architecture
 - 해당 시험 방법 이해 What does the standard say?
 - 태양빛의 전체 스펙트럼 필요? Is full spectrum important?
 - 수분 침투의 중요성? How important is water uptake?

Thank you for your time.

Questions?

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We make testing simple. |

