粉末涂料耐候老化测试研究

— 实验室加速测试与户外曝晒之间的相关性

Weathering Testing of Powder Coatings

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Q-Lab公司

- 成立于1956年
- 专注于材料耐候老化、耐腐蚀测试设备及测试服务

Cleveland , Ohio
Headquarters & Instrument Division

Bolton, England
Q-Lab Europe

Shanghai, China
Q-Lab China

Saarbrücken, Germany
Q-Lab Germany

Q-Lab户外曝晒场和加速实验室

佛罗里达

亚利桑那

俄亥俄州

实验室加速

内容
Content

- 耐候老化测试机理
- 实验室加速老化测试及户外曝晒技术
- 粉末涂料加速老化测试与Florida户外曝晒之间的相关性

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.

由于暴露于阳光中受到紫外辐射，以及热（包括温度循环）和水（主要是湿度、露水和雨水）而导致的材料性能的变化。

Forces of Weathering

Know Your Enemy!

- Sunlight

阳光

- Heat

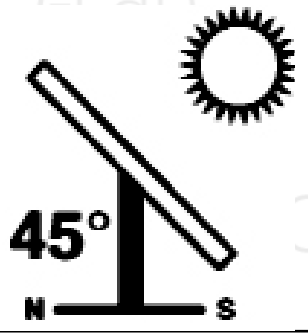
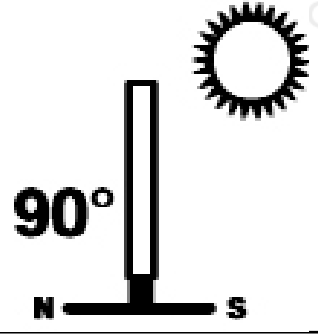
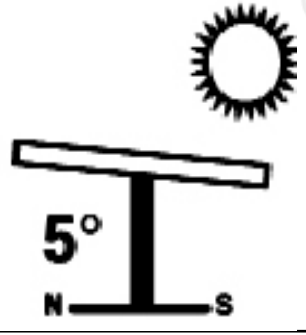
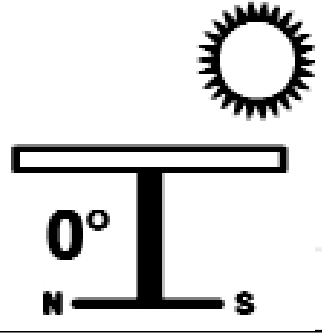
热

- Water

水

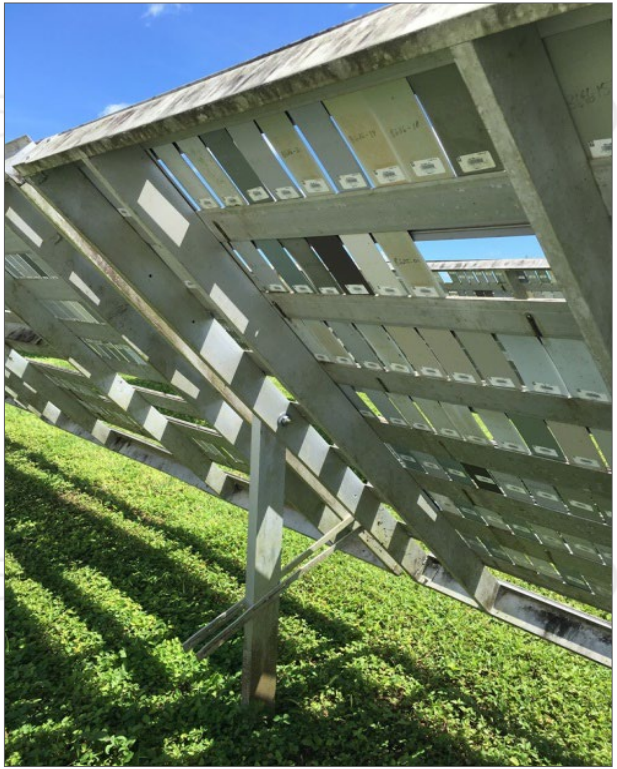
**Other factors can impact weathering as well but we will not focus on those today*

Exposure Angles

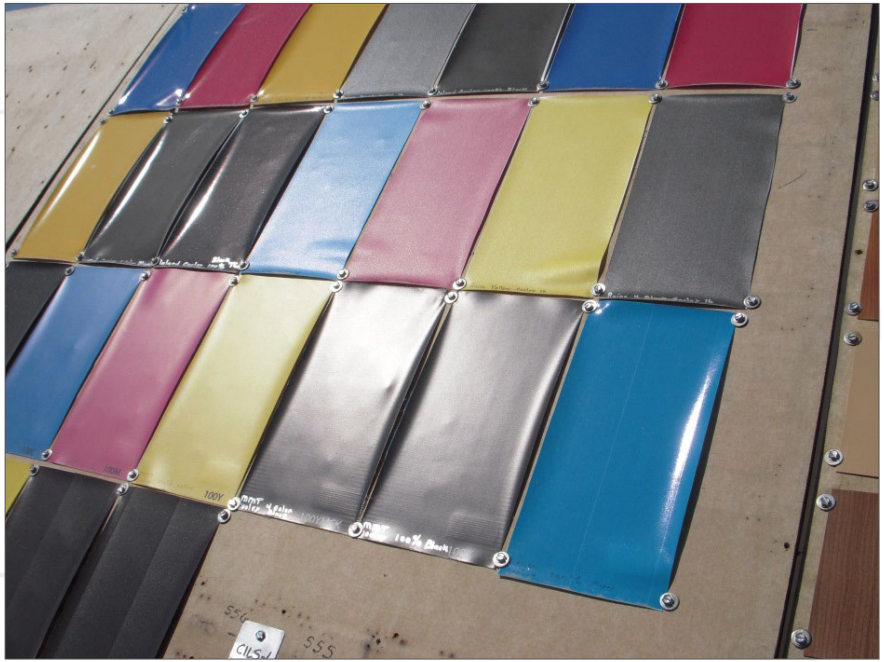
	45° South	90° South	5° South	0°
Graphic				
Orientation	Faces Equator (north in southern hemisphere)			Horizontal
Materials commonly tested	• Powder/coil coatings • Corrosion tests • Outdoor plastics	• Window profiles • Vinyl siding • Architectural coatings	• Automotive coatings • Roofing materials • Outdoor flooring	• 3D parts • Roofing
Comment	Most commonly used outdoor exposure	Reduced solar exposure Vertical end-use	Increased wet time	Highest time of wetness

45° South Exposure Angle

Open-Backed Exposure



Plywood-Backed Exposure



实验室加速试验
Lab Accelerated Weathering Test

- Q-SUN 氙灯试验箱
- Q-SUN xenon test chamber

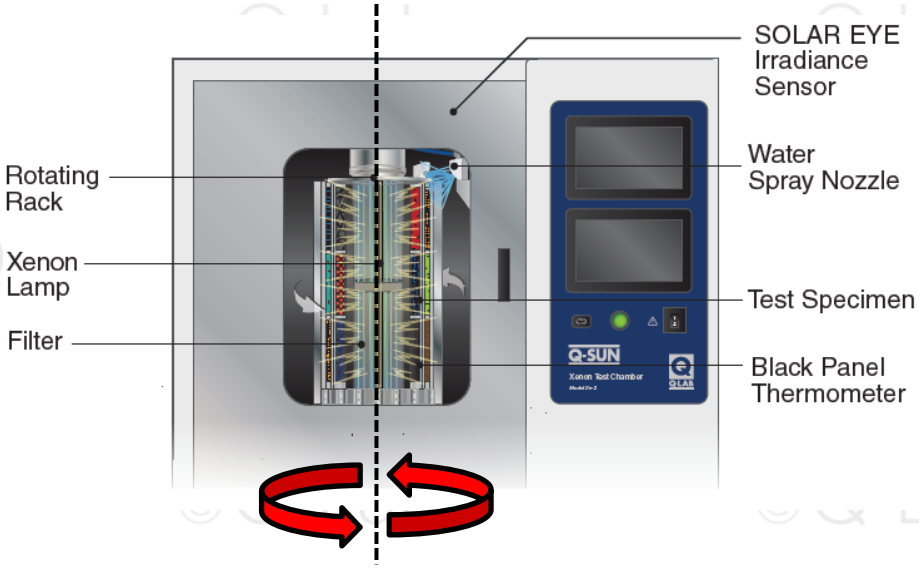
- QUV 紫外老化试验机
- QUV accelerated weathering tester

实验室加速试验
Lab Accelerated Weathering Test

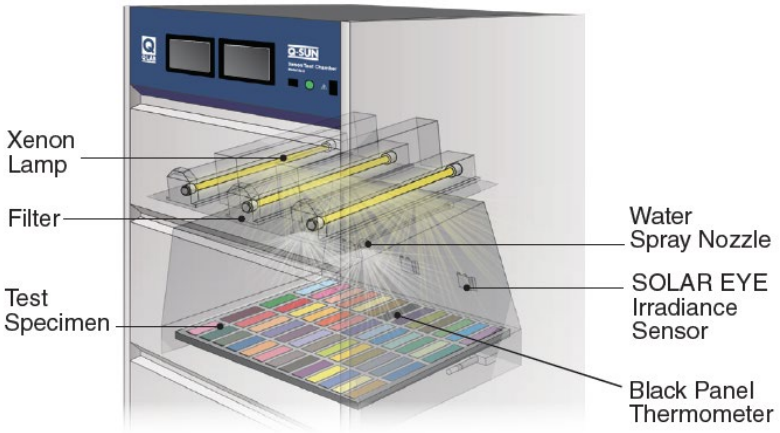
Q-SUN氙灯试验箱

QUV紫外老化试验机

Xenon Arc Test Chamber
氙灯老化测试箱

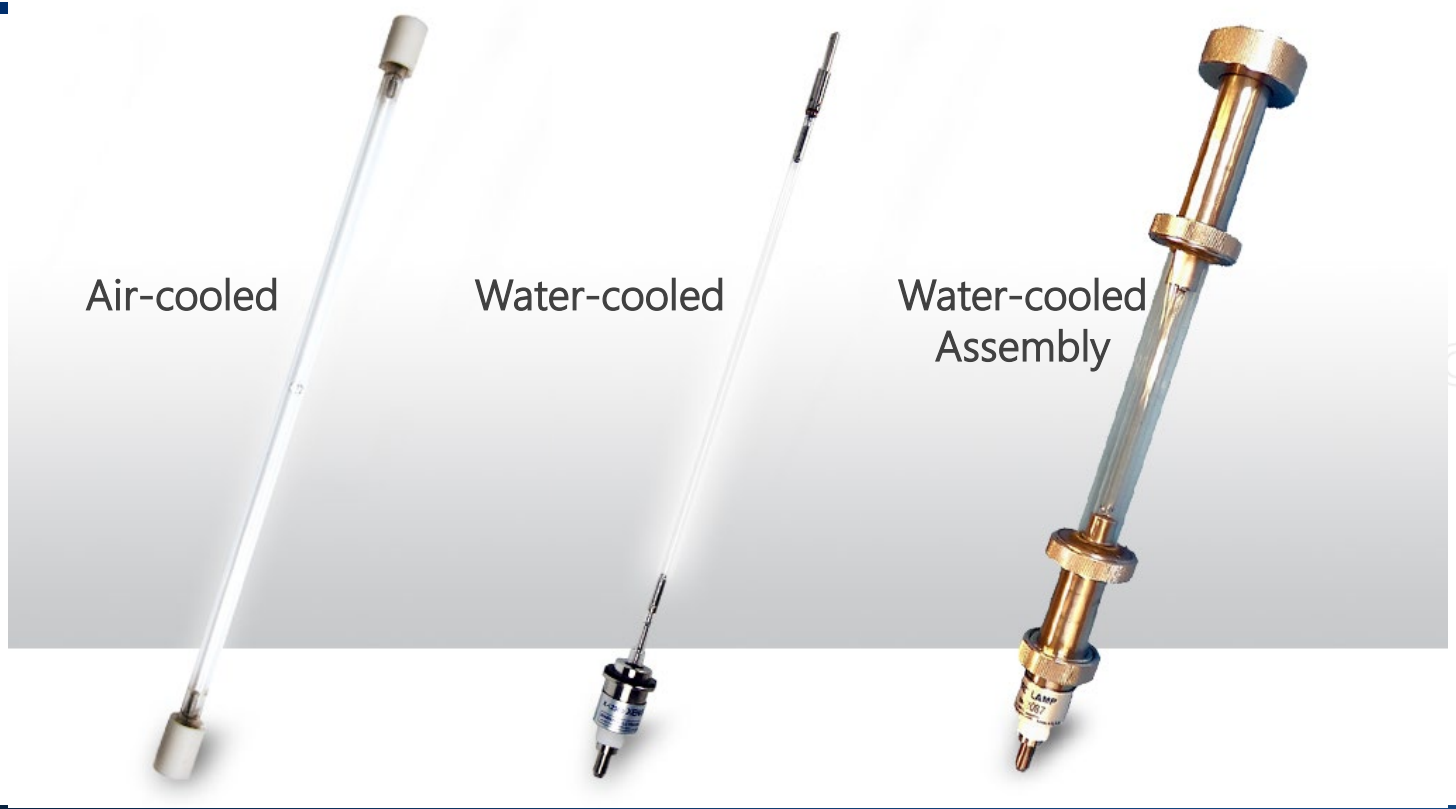


Rotating Rack
转鼓式



Flat Array
平板式

Xenon Arc Lamps
氙弧灯管



Xenon Arc Spectra - Major Influencing Factors
氙灯光谱 – 主要的影响因素

- Optical filters

光过滤片

- Irradiance level (intensity)

辐照强度

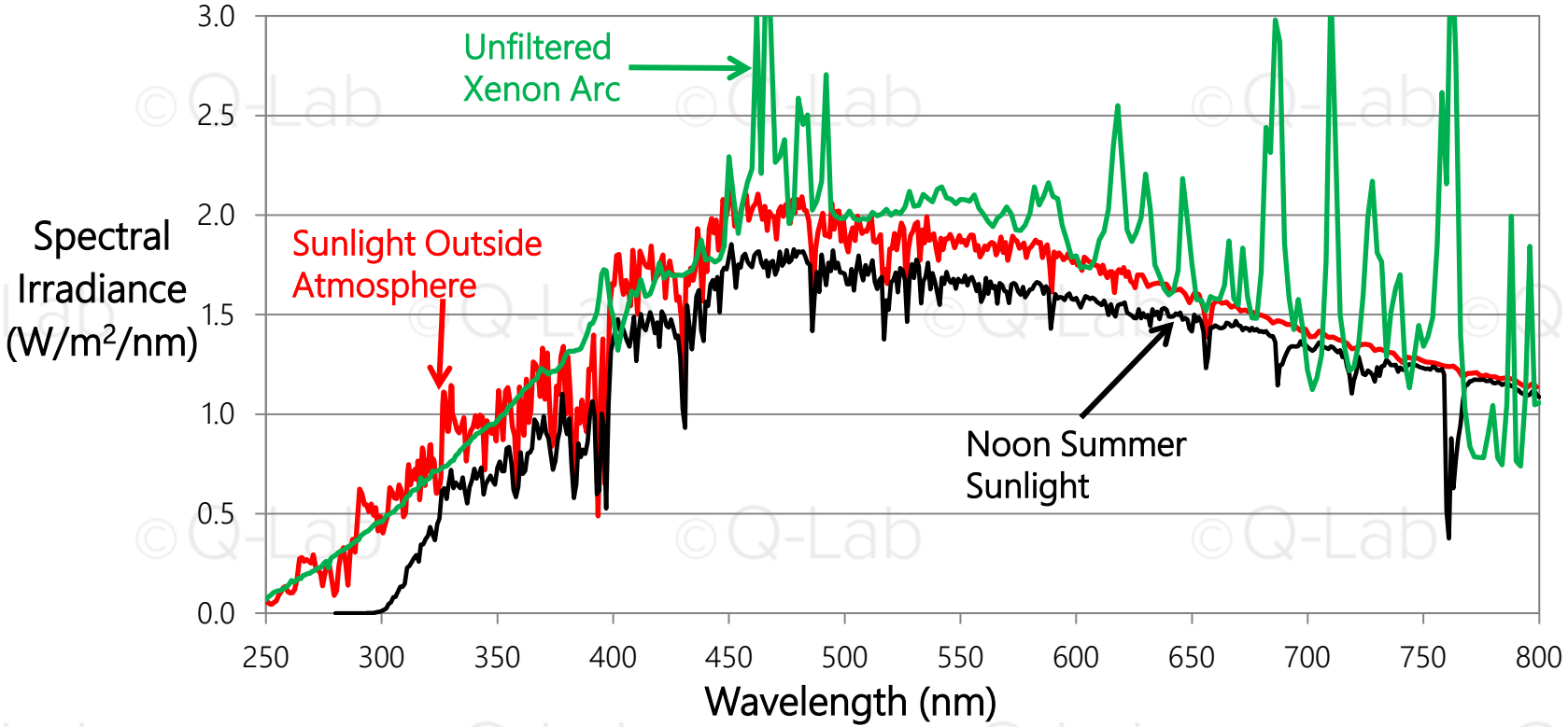
- Wavelength at which irradiance is controlled (“control point”)

辐照度控制点

- Lamp aging

灯管老化

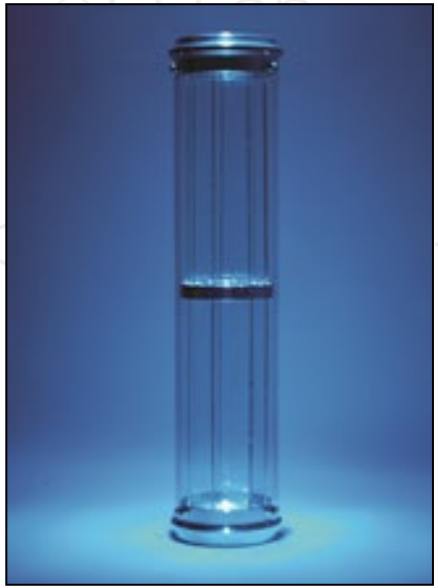
Unfiltered Xenon Arc vs. Sunlight
未过滤氙灯 vs. 太阳光



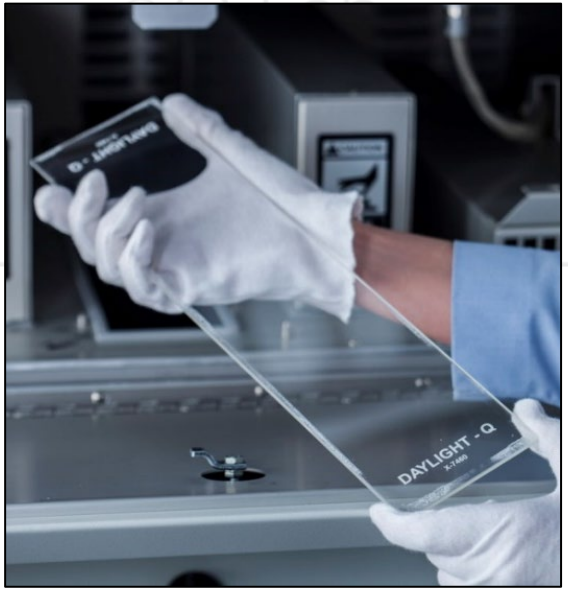
Overview of Filters
过滤片总结

- Daylight 日光
- Window 窗玻璃
- Extended UV 紫外延展

Rotating drum “lantern”

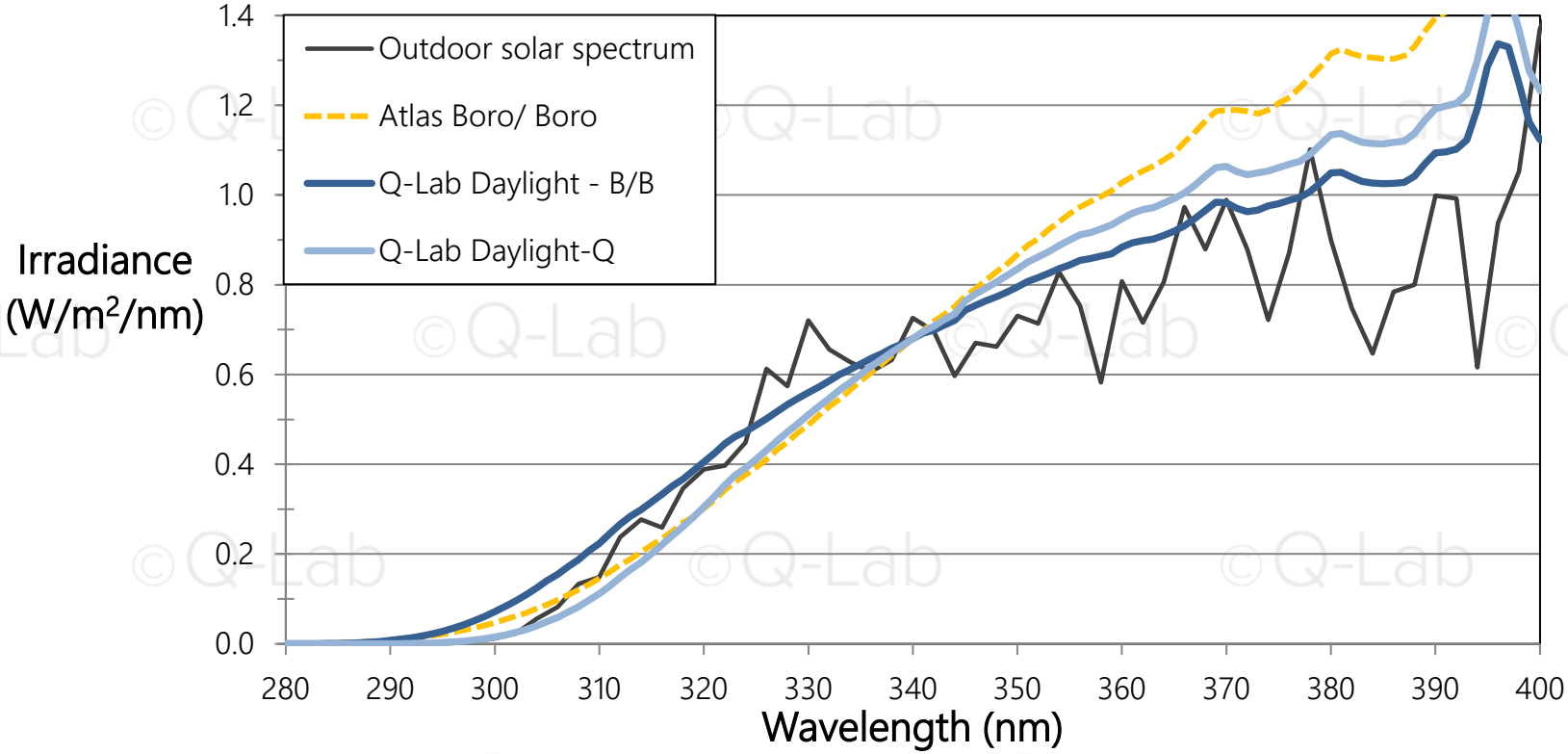


Flat array filter



Other specialized filters used occasionally

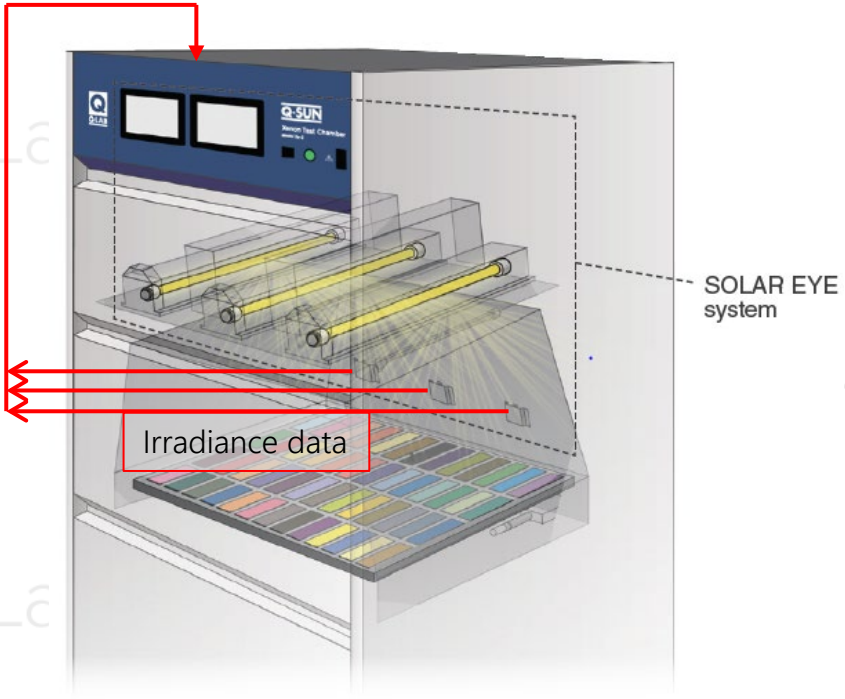
Daylight Filter Comparison
日光滤片的比较



Q-SUN SOLAR EYE™
Irradiance Control

- Feedback Loop Control 闭环反馈
  - Xenon-arc lamp 氙灯
  - Light sensor 光探头
  - Control module 控制模块
- Wavelength at which irradiance is controlled is referred to as Control Point

控制辐照度的波长称为控制点



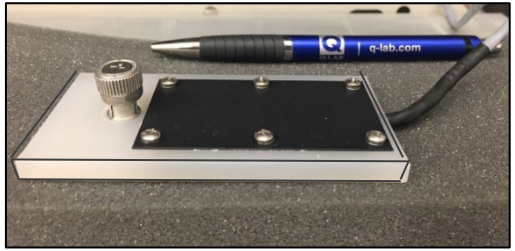
Irradiance Control Point Options
辐照度控制选项

- Narrow Band 窄带
  - 340 nm
  - 420 nm
- Wide Band 宽带
  - Total UV TUV (300-400 nm)
  - Global (300-800 nm) – not recommended 不推荐300-800nm控制
    - Shorter wavelengths cause more photodegradation

    短波造成光老化
    - Fails to account for xenon lamp aging

    无法弥补灯管老化产生的问题

Black Panel Temperature Sensors
黑板温度传感器

Panel	Construction	ASTM Designation	ISO Designation
	Black painted stainless steel	Uninsulated Black Panel 非绝缘黑板	Black Panel 黑板
	Black painted stainless steel mounted on 0.6 cm white PVDF	Insulated Black Panel 绝缘黑板	Black Standard 黑标

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

Chamber Air Temperature Control
空气温度控制

- Required by certain test methods

有些标准要求

- Necessary for control of relative humidity (RH)

湿度控制时候是需要空气温度控制的

- Sensor must be shielded from light

探头必须避光

- BP temp always hotter than chamber air temp from absorbing radiant heat

黑板温度在光照下大于空气温度

Relative Humidity Control
相对湿度控制

- Required by many test methods

很多测试需要湿度控制

  - Textiles 纺织
  - Automotive 汽车

- Many xenon testers can generate and control relative humidity

很多设备可以控制相对湿度

  - Boiler-type system 蒸汽
  - Nebulizer system 超声波

- For many durable materials, RH makes very little difference compared to spray and condensation

对很多耐候产品，相较于水喷淋和冷凝，湿度产生的作用很小

Xenon Arc Water Spray
氙灯水喷淋

Front spray 前喷

- Primary method of water delivery

水施加的主要方法

- Calibration technique for front spray recently developed (ASTM D7869)

ASTM D7869对喷淋收集量的校准

Back spray 背喷

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

为产生冷凝而开发的失败实验，一些标准中存在

Dual spray 双喷淋

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

施加第二种溶液， 比如酸雨

Immersion (Ponding) 水浸

- Alternative to front spray called out in some standards

替代某些标准中规定的前喷淋

Xenon Arc Summary

- Best simulation of full-spectrum sunlight

全光谱太阳光模拟

- Lamps experience aging (fulcrum effect)

灯管老化（支点效应）

- Temperature effects

温度影响

- Water spray and RH control

水喷淋和湿度控制

- Additional cost, maintenance, and complexity compared to fluorescent UV testers

和荧光紫外相比，成本更高，维护更复杂

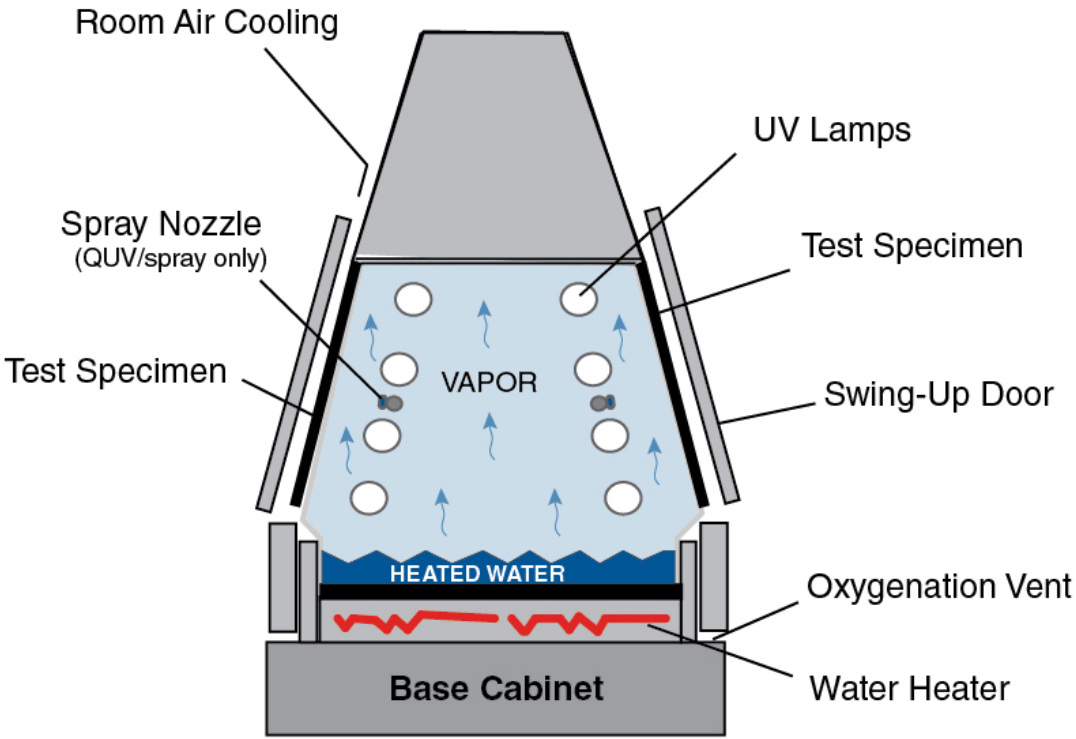
Q-SUN Xenon Arc Testers

Xe-1

Xe-2

Xe-3

Fluorescent UV Schematic
荧光紫外示意图

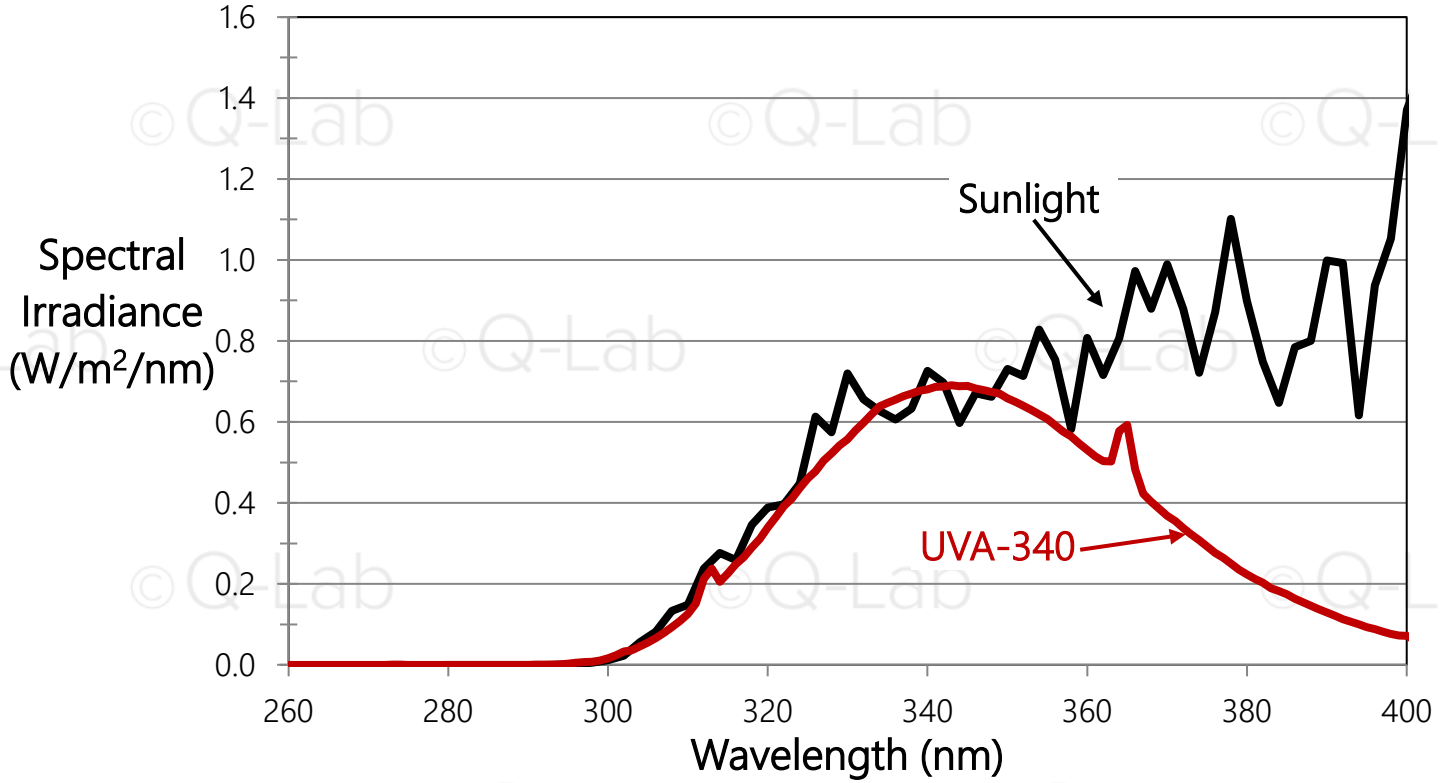


Fluorescent UV Lamps

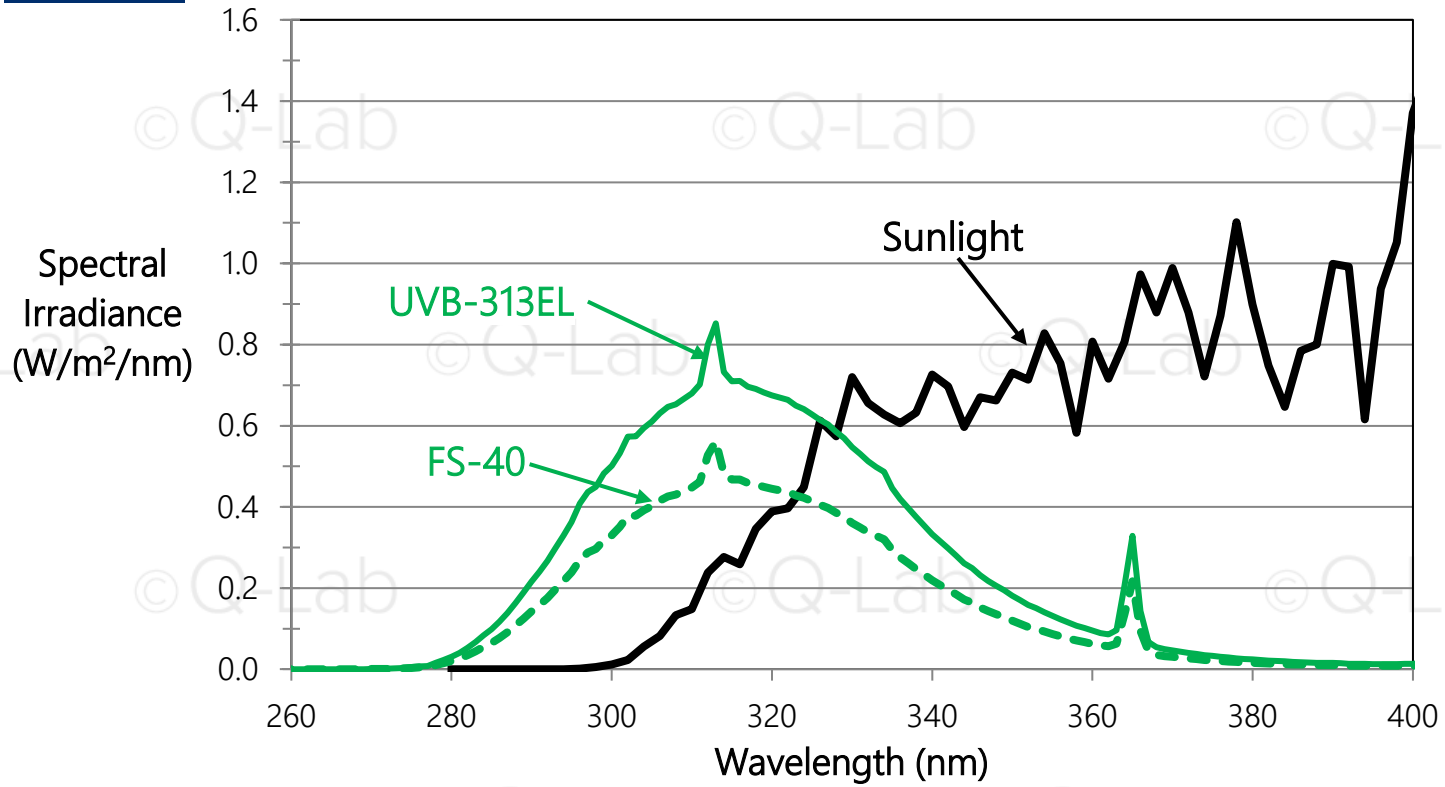
QUV Lamp Summary

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

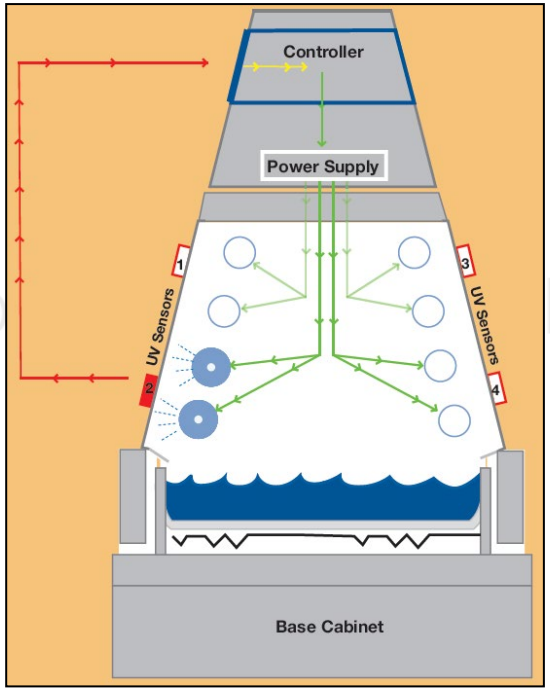
UVA-340 Lamps



UVB Lamps



QUV SOLAR EYE™ Irradiance Control



Feedback Loop Control

闭环反馈控制

- Fluorescent UV lamp 紫外灯
- Light sensor 光探头
- Control module 控制模块

Fluorescent Lamp Advantages
荧光紫外灯优势

- Fast Results

快速结果

- Simplified irradiance control

简化辐照度控制

- Very stable spectrum – no aging

光谱稳定 – 不老化

- Low maintenance

低维护

  - Simple calibration 校准简单

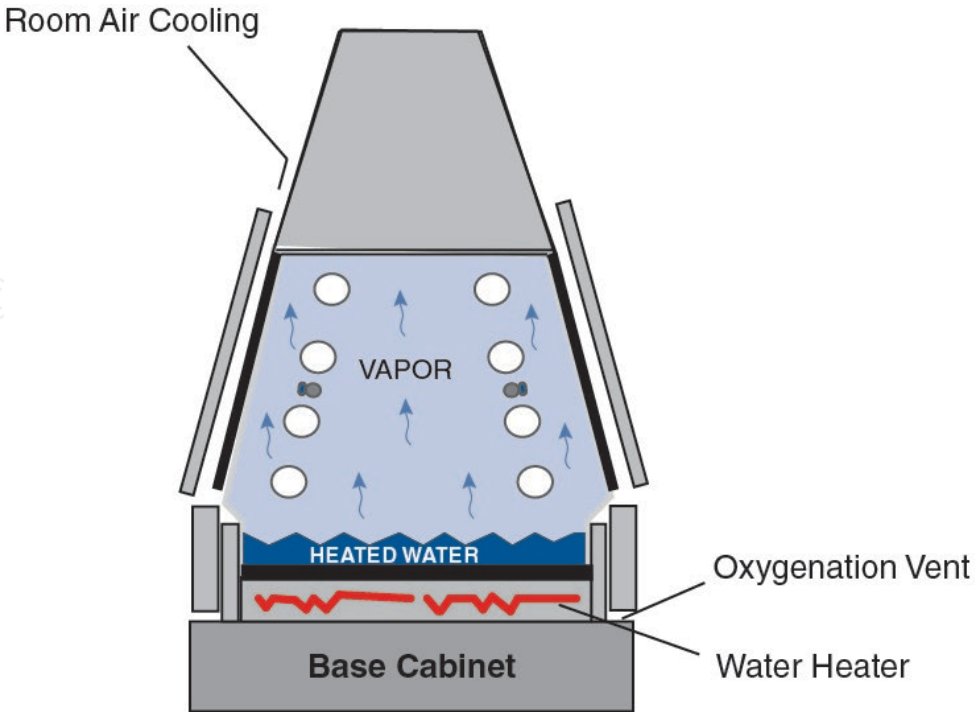
- Low price and operating cost

低购机成本和运行成本

- Simple and easy to maintain

维护简单

Condensation 冷凝



Water Spray 水喷淋

- Ensures that parts get fully saturated

保证样品充分水饱和

- Creates erosion & thermal shock

产生腐蚀和热冲击

Creating spray in the QUV is difficult and relatively expensive
在QUV中做水喷淋是困难和昂贵的

Fluorescent UV Summary

- UVA-340 best simulation of short-wave UV

UVA-340灯管最好地模拟短波紫外

- UVB-313 fastest & most severe

UVB-313灯管老化测试快

- Stable spectrum – no aging

稳定的光谱 – 不老化

- No visible light

没有可见光

- Condensation realistic & rigorous

冷凝真实模拟露水，充分潮湿

- Water spray available but not RH control

有水喷淋但没有湿度控制

QUV Accelerated Weathering Tester

Model QUV/se

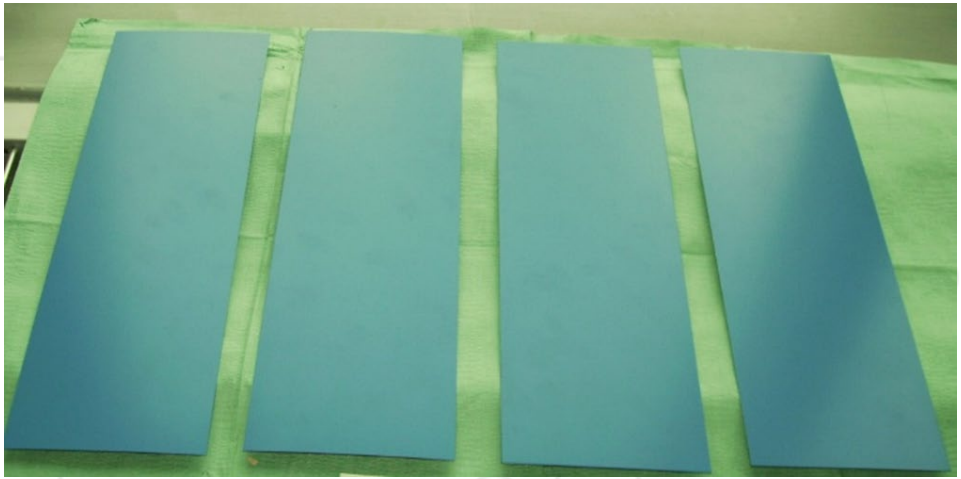
Fluorescent UV and Xenon Arc - Complementary Technologies
荧光紫外和氙灯 – 互补技术

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 • Condensation or water spray	• RH control • Water spray
• Inexpensive, simple to use	• More complex system

户外 vs. 实验室
Outdoor Exposure vs. Lab Testing

+

试验样品
Test Specimens



Why Florida?
为什么选择佛罗里达?

- High UV irradiance
高紫外

- High temperatures
高温

- High time of wetness (TOW)
高潮湿时间

- High humidity
高湿度

氙灯加速老化试验条件
Xenon accelerated weathering test conditions

测试设备 tester	氙灯加速老化试验箱 Xenon test chamber
滤光器 filter	日光滤光器 daylight filter
辐照度 irradiance	0.51 W/m^2 @340nm
黑标温度 BST	65 °C
箱体空气温度 chamber air temp	38 °C
相对湿度 HR	50 %
喷淋 spray	102 mins sunlight；18 mins sunlight +spray

注：以上试验条件参照ISO 16474-2标准
Note : according to ISO 16474-2

紫外加速老化试验条件
UV accelerated weathering test conditions

试验设备 tester	QUV紫外加速老化试验机 UV accelerated weathering tester
试验灯管 lamp	UVA-340灯管 UVA-340 lamp
辐照度 irradiance	1.55 W/m^2@340nm
黑板温度 BPT	60 °C（光照循环）(UV step) 50 °C（冷凝循环）(condensation step)
测试循环 test circle	8h（光照循环）(UV step) 4h（冷凝循环）(condensation step)

注：以上试验条件参照ASTM G154 测试循环6
Note : according to ASTM G154 Cycle 6

紫外加速老化试验条件
UV accelerated weathering test conditions

试验设备 tester	QUV紫外加速老化试验机 UV accelerated weathering tester
试验灯管 lamp	UVB-313灯管 UVB-313 lamp
辐照度 irradiance	0.71 W/m^2@310nm
黑板温度 BPT	60 °C（光照循环）(UV step) 50 °C（冷凝循环）(condensation step)
测试循环 test circle	4h（光照循环）(UV step) 4h（冷凝循环）(condensation step)

注：以上试验条件参照ASTM G154 测试循环2
Note : according to ASTM G154 Cycle 2

相关性 Correlation

Definition of Correlation: “The agreement of results between outdoor and accelerated tests”
-ASTM G113

相关性：“户外数据和实验室加速数据之间的关联性”

-ASTM G113

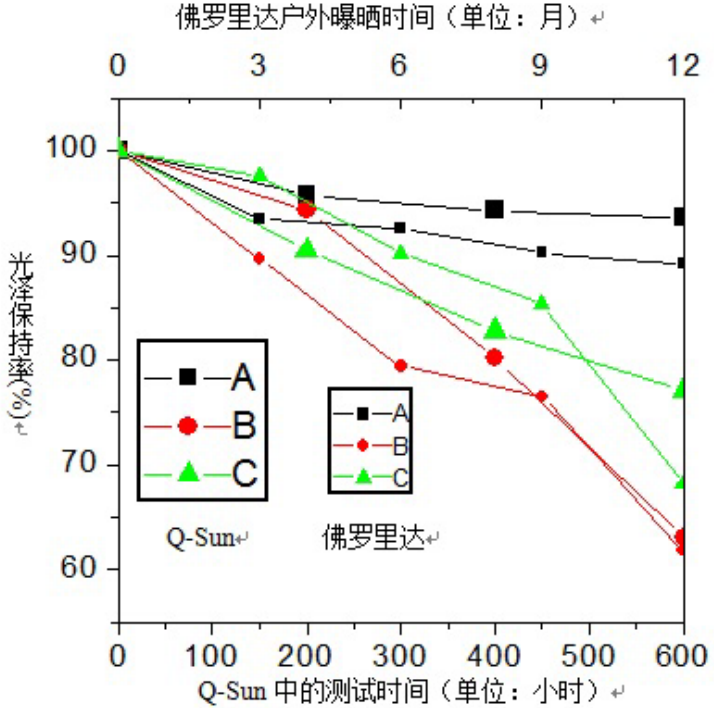
相关性
Correlation

- 利用排序方法来确认曝晒结果
  - Apply the method of rank order to confirm the exposure result
- 把样品从好到差或从差到好进行排序
  - Rank specimens from best to worst
- 使用Spearman相关系数计算两种方法之间的相关性
  - Calculate Spearman Correlation Coefficient between the two methods
  - $r_s=1-6\sum d_i^2/[n(n^2-1)]$
- 相关系数最大为1，最小为-1
  - Spearman Correlation Coefficient is from -1 to 1

Q-SUN与Florida测试结果之间的比较

- 按照Q-SUN测试程序运行800小时
- 佛罗里达户外曝晒1年
- 计算Q-SUN与佛罗里达测试，样品失光率之间的相关系数
- Q-SUN试验600h与佛罗里达曝晒1年结果相当
- Q-SUN试验600h与佛罗里达曝晒1年相关系数0.9

Q-SUN与Florida测试结果之间的比较



Q-SUN测试600h与Florida曝晒1年样品失光率之间的比较

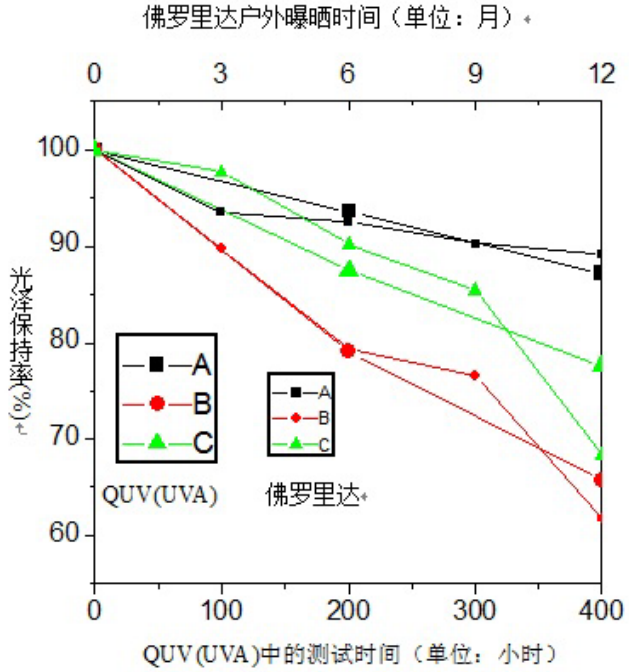
Q-SUN与Florida测试结果之间的比较

- 无论是使用Q-SUN对样板进行测试还是Florida户外曝晒，样板的光泽均发生退化
- A样板光泽保持的较好，B样板的光泽下降最低
- Q-SUN测试与Florida户外曝晒之间的相关性较好

QUV(UVA-340)与Florida测试结果之间的比较

- 按照QUV (UVA-340)测试程序运行1000小时
- Florida户外曝晒1年
- 计算QUV (UVA-340)与Florida测试，样品失光率之间的相关系数
- QUV (UVA-340)试验400h与Florida曝晒1年结果相当
- QUV (UVA-340)试验400h与Florida曝晒1年相关系数0.9

QUV(UVA-340)与Florida测试结果之间的比较



QUV (UVA-340)测试400h与Florida曝晒1年样品失光率之间的比较

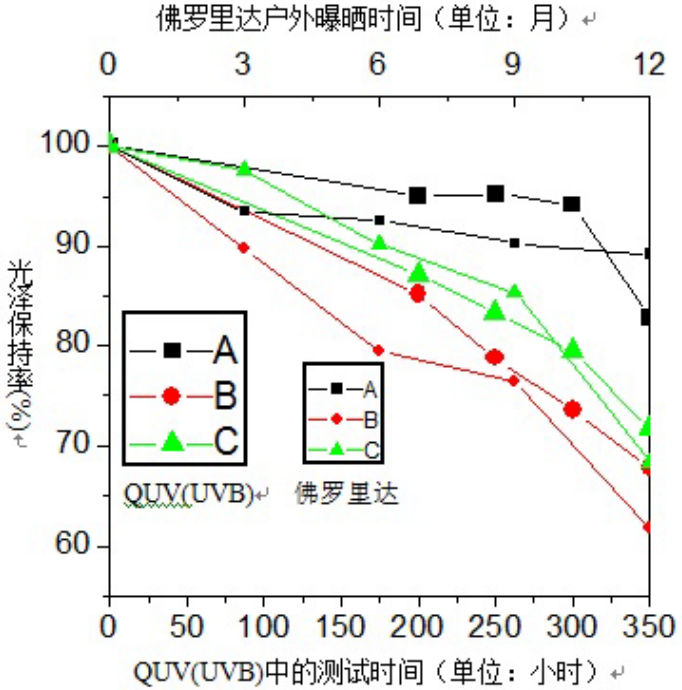
QUV(UVA-340)与Florida测试结果之间的比较

- 无论是使用QUV (UVA-340)对样板进行测试还是Florida户外曝晒，样板的光泽均发生退化
- A样板光泽保持的较好，B样板的光泽下降最低
- QUV (UVA-340)测试与Florida户外曝晒之间的相关性较好

QUV(UVB-313)与Florida测试结果之间的比较

- 按照QUV (UVB-313)测试程序运行400小时
- Florida户外曝晒1年
- 计算QUV (UVB-313)与Florida测试，样品失光率之间的相关系数
- QUV (UVB-313)试验350h与Florida曝晒1年结果相当
- QUV (UVB-313)试验350h与Florida曝晒1年相关系数0.9

QUV(UVB-313)与Florida测试结果之间的比较



QUV (UVB-313)测试350h与Florida曝晒1年样品失光率之间的比较

QUV(UVB-313)与Florida测试结果之间的比较

- 无论是使用QUV (UVB-313)对样板进行测试还是Florida户外曝晒，样板的光泽均发生退化
- A样板光泽保持的较好，B样板的光泽下降最低
- QUV (UVB-313)测试与Florida户外曝晒之间的相关性较好

结论
Conclusions

- 户外测试是实验室加速老化测试的基础

- 无论是Q-SUN氙灯试验箱，还是QUV紫外老化试验机对材料造成的失光与户外曝晒之间的相关性都较好

- QUV紫外老化试验机比Q-SUN氙灯试验箱能更快模拟Florida户外曝晒1年的效果

Thank you for your attention!

Questions?

Send your inquiry to:
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