

Modern Automotive Weathering Testing: ASTM D7869 汽车老化测试：ASTM D7869

Standard Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings

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What is Weathering? 什么是老化？



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.

Why Do Weathering Testing? 为什么做老化测试？



High gloss and color integrity
光泽高，颜色完好

OR



Fading, cracking, peeling
褪色，开裂，剥落

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

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Qualification / Correlative Testing 鉴定/相关性测试

Accelerated Test Type 类型	Result 结果表示	Test Time 测试时间	Results compared to 结果比较
Quality Control 质量控制	Pass / fail 合格/不合格	<ul style="list-style-type: none"> • Defined 确定的 • Short 较短 	Material specification 材料规格
Qualification / validation 鉴定/验证	Pass / fail 合格/不合格	<ul style="list-style-type: none"> • Defined 确定的 • Medium-long 中长 	Reference material or specification 参考材料或规范
Correlative 相关性	Rank-ordered data 排序	<ul style="list-style-type: none"> • Open-ended 不确定 • Medium 中等 	Natural exposure (Benchmark site) 自然曝晒 (基准曝晒场)
Predictive 预测	Service life 使用寿命 Acceleration factor 加速因子	<ul style="list-style-type: none"> • Open-ended 不确定 • Long 较长 	Natural exposure (Service environment) 自然曝晒 (使用环境)

Historical Xenon Test Standards 氙灯测试标准

- Carbon Arc and Xenon arc weathering testing have been performed for over 100 years 碳弧灯和氙弧灯老化测试已100多年
- Xenon testers reproduce full-spectrum sunlight 氙灯试验箱模拟全光谱太阳光
- Hardware-based “102/18” light / light+spray standards were the first widely-used weathering standard tests
- 以硬件为基础的 “102/18” 光照/光照+喷淋标准是最早被广泛使用的老化测试方法
 - Almost 100 years old but still in use
 - Most common examples are ISO 4892-2 and ASTM G155
 - *Not realistic!*

Accelerated Weathering Tests 加速老化测试

Commonly Used on Automotive Parts

International standards

- ASTM G154/G155
- ISO 4892-2, -3
- SAE J2412
- SAE J2527
- ASTM D7869

Automaker standards

- Renault D27-1911
- VW PV 1303, PV 3929
- Daimler DBL 5555
- Fiat 50451
- Ford BO 116
- Toyota TSL 3600G

Most are for QC/Qualification purposes

The Industry Standard: SAE J2527 行业标准: SAE J2527

- SAE J2527 introduced in 1980's SAE J2527开发于上世纪80年代
 - Authors researched light, water, heat 研究了光·水·热
 - Test replicated gloss loss seen in Florida 测试再现了Florida的光泽损失
- Standard was well-researched but did not match real-world weathering factors
- 标准与实际的老化因素不完全匹配
 - Light spectrum 光谱
 - Water delivery 水的施加
- As a result, test does not always predict Florida outdoor field failures
- 测试并不总是能预测Florida户外曝晒的失效模式
 - Chemical changes 化学变化
 - Physical changes 物理变化

Why Develop a New Standard? 为什么开发新标准？

- SAE J2527 was developed to reproduce common failures of coatings in that era, primarily color fade and gloss loss.
- SAE J2527的开发是为了再现那个时代涂层的常见失效模式，主要是褪色和失光
- Over years, coatings became very resistant to color fade and gloss loss, and SAE J2527 doesn't reproduce more common failures in modern coatings, primarily cracking and delamination.
- 多年来，涂层的颜色和光泽性能变好，而SAE J2527无法再现现代涂层中常见的失效模式，主要是开裂和层离

ASTM D7869: Modern Weathering Testing

ASTM D7869: 现代老化测试



Designation: D7869 – 17

**Standard Practice for
Xenon Arc Exposure Test with Enhanced Light and Water
Exposure for Transportation Coatings¹**

Development Process 开发过程

- Outdoor weather data collected to understand real-world weather conditions: light, heat, and water
- 收集户外气候数据，以了解真实的天气状况：光，热和水
- Outdoor weathering test dataset collected to provide basis for correlation
- 收集户外老化测试数据，为相关性提供依据
- Accelerated test cycle developed to match those real-world conditions and degradation mechanisms
- 开发加速测试循环，以模拟实际条件和老化机理
- Variety of materials and failure modes evaluated with accelerated testing to verify validity of test
- 通过加速试验评估各种材料和失效模式，以验证试验的有效性

Test Development 测试开发

- Many years of experimentation 进行了多年试验
 - 1st group: BASF, Bayer, Ford, Q-Lab
 - 第1组：BASF，拜耳，福特，Q-Lab
 - 2nd group: Honda, Boeing, Atlas
 - 第2组：本田，波音，Atlas
- Dozens of different approaches 数十种不同的试验方法
- Multiple runs of final test to ensure repeatability & reproducibility
- 多次运行最终测试，以确保试验的重复性和再现性

Collecting outdoor weather data

收集户外气候数据

Laying the groundwork for a new accelerated test
为新的加速试验奠定基础

Outdoor weather data 户外气候数据

Approach: collect outdoor weather data to better understanding the forces of natural weathering:

方法: 收集户外气候数据, 以更好地了解自然老化因素:

- Sunlight
- Heat
- Water



Goal: Obtain suitable body of field data to develop the Accelerated laboratory test

目的: 获得适当的户外数据, 以开展实验室加速测试

Outdoor Weather Data Collected 户外气候数据收集

- Solar Radiation (Sunlight) 太阳辐射
- Temperature 温度
 - Air, Black Panel, Relative Humidity and Dew Point
 - 气温，黑板温度，相对湿度，露点
- Wind 风
 - Speed and Direction 风速，风向
- Rain 雨
 - Amount, Duration, Rate Accumulation 雨量，持续时间，降雨率累积
- Panel Weight 面板重量
 - Wetness, Dew Events and Rain Events 湿度，露水，雨水

Outdoor Weather Data Collection Sites 户外气候数据收集地点

- Weather Station installed Jacksonville, FL (Bayer)
 - 2004 to 2007
- Moved to Homestead, FL (Q-Lab)
 - 2008 to 2014



Outdoor Weather Water Data Measurements

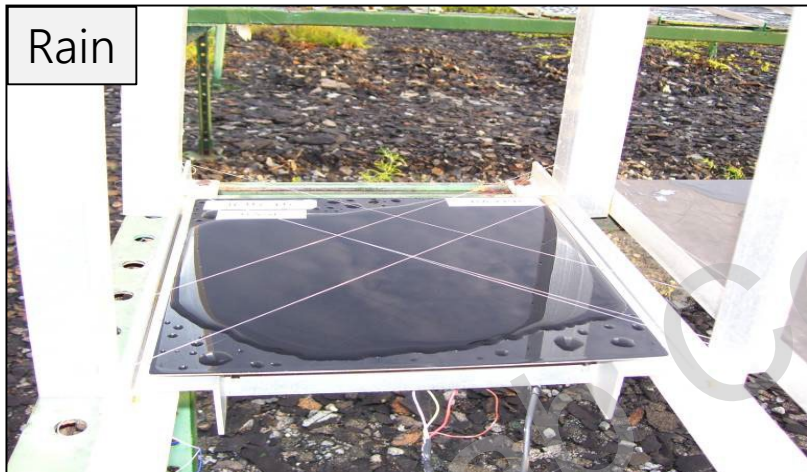
户外水数据测量

- Mass of panel measured every 5 min
 - Panel + Water
- Calibrated regularly
- Care taken to ensure no animal or bird influence
- Able to see rain vs dew + water uptake



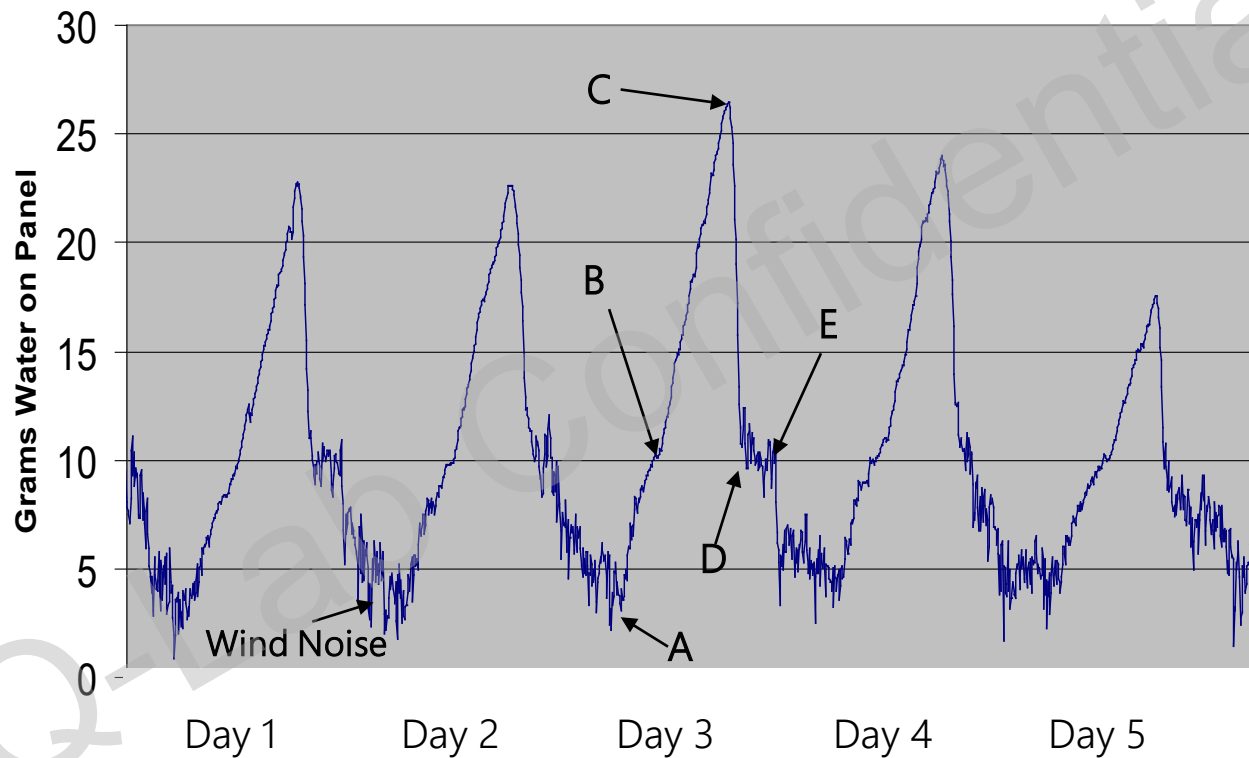
Example from Outdoor Data 户外数据示例

Water on Test Panels 测试面板上的水



Materials outdoors are wet for longer than you think!

Dew on Painted Panels 涂层面板上的露水



Key Learnings from Outdoor Benchmark Testing

Key Factors in a Correlative Weathering Test 老化试验中的关键因素

- Global benchmark location: South Florida 全球基准位置：Florida南部
- Light intensity: use higher-intensity light with correct spectrum to increase acceleration
- 辐照度：使用正确光谱的高辐照度来加快加速测试
- Heat: Keep temperatures realistic, at or below service
- 热：保持实际温度，等于或低于工作温度
- Time of wetness: Increase! Mimic real-world behavior - panels wet 12+ hrs/day in Florida
- 潮湿时间：增加！模拟真实环境 – 面板在Florida每天潮湿时间超过12小时
- Water spray: Never spray panels during light step; it never rains when sun is shining brightly!
- 水喷淋：在光照阶段不进行水喷淋



Sunlight 太阳光

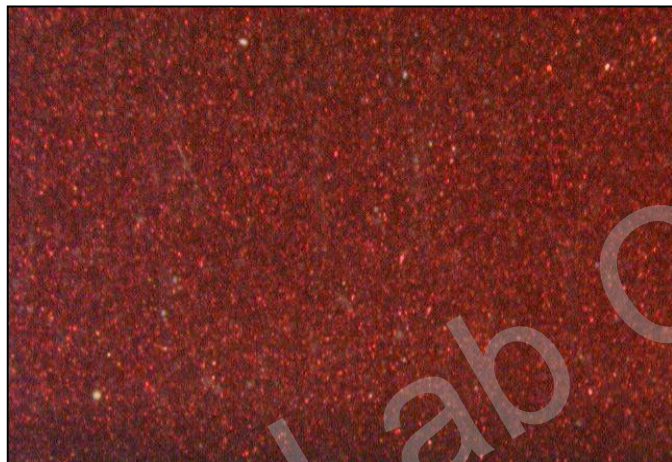
- Explored different light sources 研究不同的光源
- Explored different optical filters 研究不同的光过滤片
- Accelerated outdoor weathering (Q-TRAC) provided tantalizing results
- 加速户外曝晒 (Q-TRAC) 提供了“诱人” 的结果
- Better match to sunlight just might work, but be careful ...
- 更好地模拟太阳光可能会奏效，但要小心。 。 。



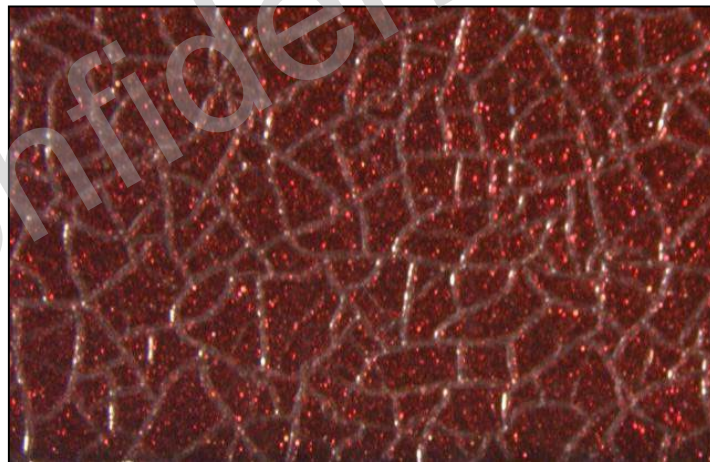
The wrong light source gives the wrong results!

错误的光源给出错误的结果！

Florida



Borosilicate filtered xenon arc



Peters/Misovski/Roberts/Lemaire/Fischer

Accelerated Light Source 加速光源

- Light source must have very good match to the solar spectrum
- 光源必须与太阳光光谱相匹配
- ASTM D7869 calls for a new optical filter ASTM D7869要求新的过滤片
 - Daylight – F (Q-Lab)
 - Right Light (Atlas)
- Produces more realistic results 得到更真实的结果
 - Higher irradiance 较高辐照度
 - Better, more realistic acceleration 更好 · 更真实的加速

Heat 热

- High temperature serves primarily to accelerate water uptake.
- 高温主要用于加速水分吸收
- Two key guiding principles: 两项关键原则：
 - Do not exceed maximum service temperature
 - 不要超过最高实际温度
 - Use realistic temperatures to increase correlation
 - 使用真实温度增加相关性



Water contributes to material degradation in many ways

水导致材料降解

- Plasticization 塑化
- Swelling 溶胀
- Blistering 起泡
- Adhesion 附着力
- Mass transport 传质
- Mass loss 失重



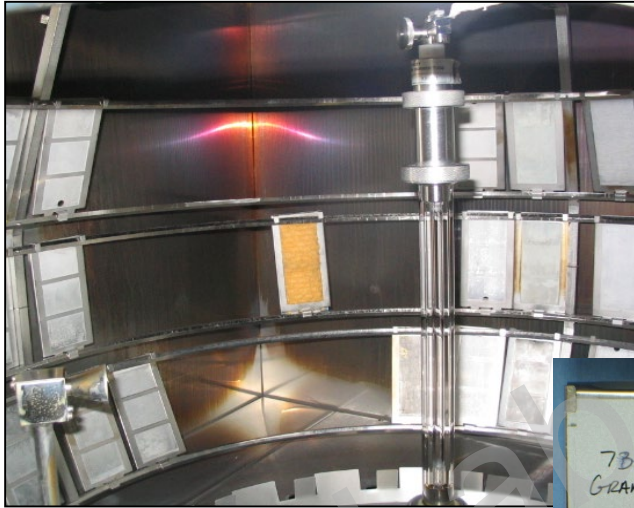
Water Delivery Calibration: Sponge Test

水的施加校准：海绵试验

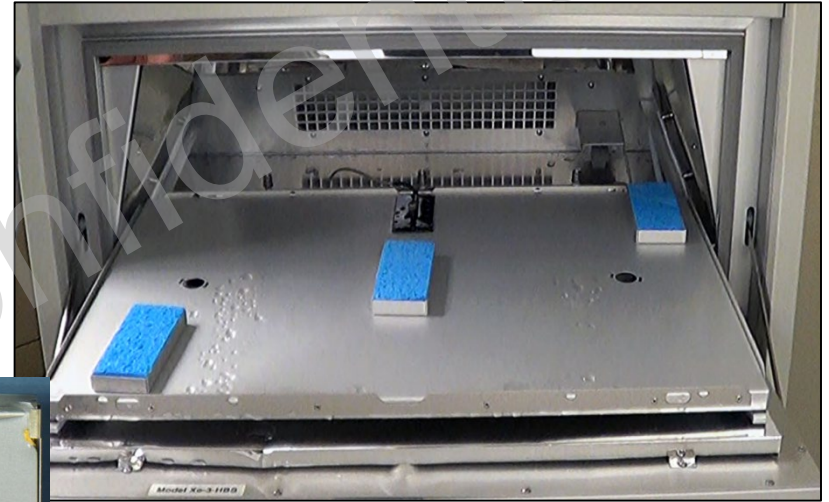
- Determine actual water delivery to specimens in both flat array & rotating drum testers
- 在平板式和旋转式氙灯试验箱中测定试样的实际供水量
- Same sponge in both machines 两种试验箱中放置相同的海绵
- Results are Repeatable & Reproducible 结果可重复&可再现

Sponge Water Calibration Tests 水施加校准试验

Rotating Rack

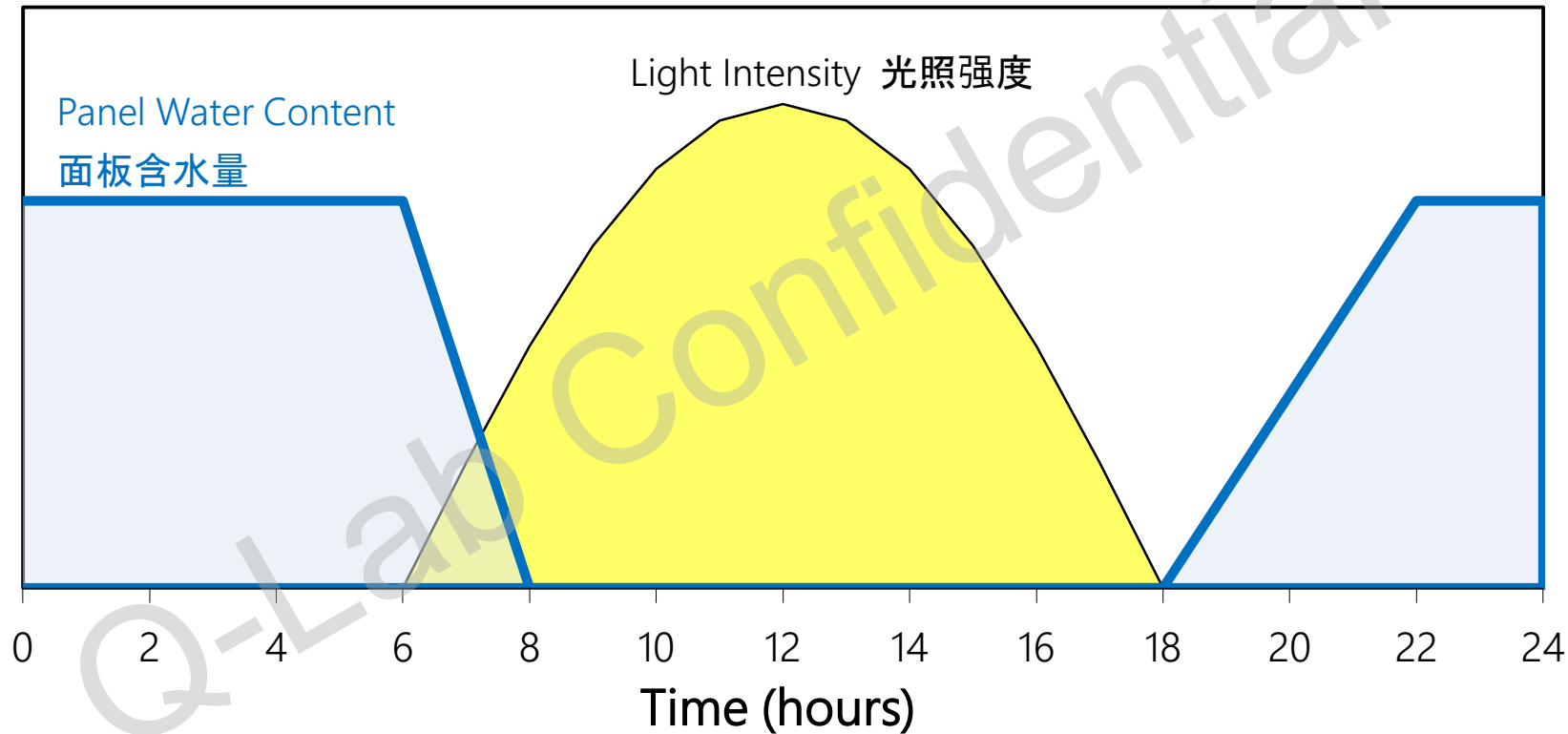


Flat Array



Shielded sponge holder

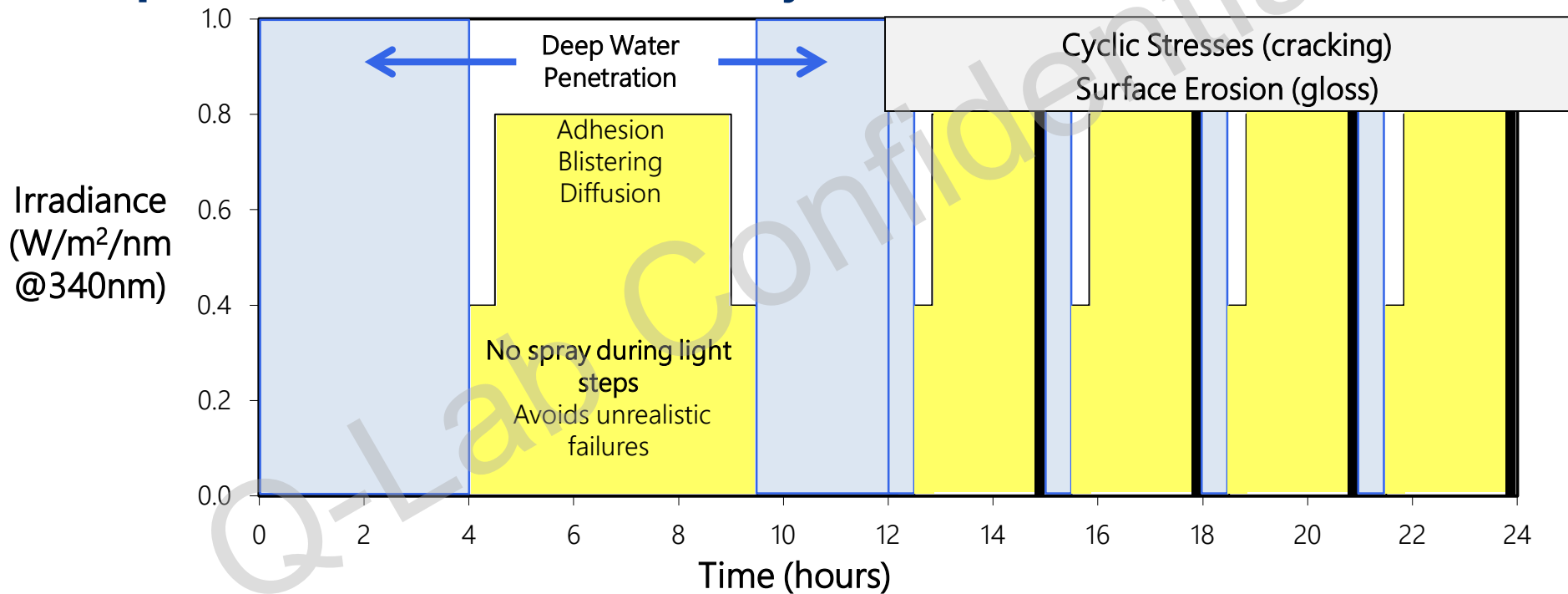
Florida outdoor daily cycle Florida户外日循环



ASTM D7869

Reproduces Natural Weather Cycles 再现自然循环

Irradiance
Water Spray



Validating the test method 验证试验方法

Putting the ASTM D7869 protocol to the test

Paint Systems Tested 涂层体系

Automotive 汽车

- ~20 systems, multiple colors 大概20种涂层体系, 多种颜色
- All systems were base coat / clear coat 所有涂层均为底漆/清漆
- Fortified and unfortified 强化和非强化
- Positive controls & known Florida exposure failure mechanisms
- 已知Florida曝晒失效模式

Aerospace 航空航天

- Four systems, two colors (blue and white) 4种涂层体系, 两种颜色(蓝色和白色)
- Two monocoat systems, two base coat / clear coat systems
- 两种单涂层体系, 两种底漆/清漆体系
- Florida, and in-service performance known 已知Florida及实际应用的性能

Outdoor Testing: Sample selection 户外测试：试样选择

- Sample set includes both common field failures & controls
- 试样包括常见的户外失效及参照样
- 106 Combinations Prepared 106种不同试样
 - 4 colors: Black, White, Blue, Red 4种颜色：黑·白·蓝·红
 - Waterborne & Solventborne Base 水性&溶剂型底漆
 - Solventborne Clear 溶剂型清漆
 - Different layering systems 不同分层体系
 - With and without Stabilizers 有/无稳定剂
- All Samples prepared by one lab
- 所有试样由同一实验室制备



Outdoor Testing: Test Protocol 户外测试：试验方案

- Testing conducted per SAE J1976
- 根据SAE J1976进行测试
- Evaluations every 6 months 每6个月评估一次
- Exposure times 曝晒时间
 - Full Set Summer 2006
 - Partial Set Summer 2007
 - Expose Until Failure 曝晒至失效



Reproducing Failure Mechanisms 再现失效模式

- Chemical changes 化学变化
- Cracking 开裂
- Blistering 起泡
- Adhesion loss 附着力损失
- Color 颜色
- Gloss loss 光泽

Important to “test the test” and validate that the scientific approach to standard development leads to good correlation with natural exposures

“test the test”很重要，并验证标准制定的科学方法与自然曝晒的良好相关性

Control System 参照样体系

Florida Exposure

SAE
J2527

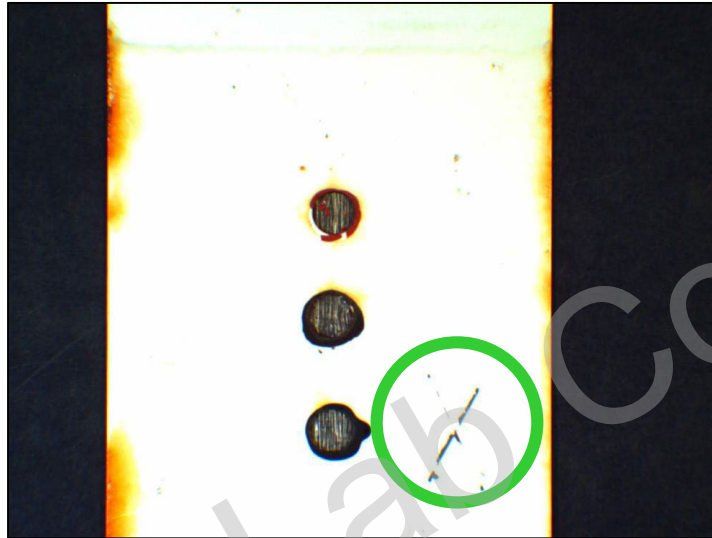
ASTM
D7869



Expected Failure Mode: None – positive control
Observed: Excellent performance in all tests

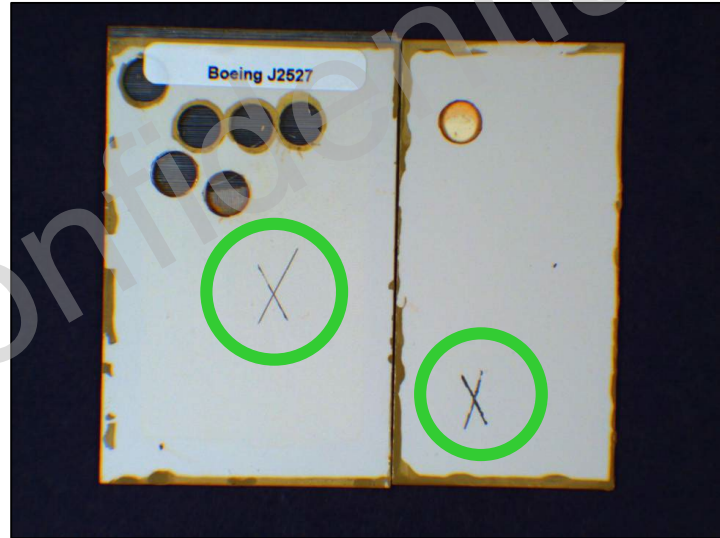
Coating Pick-Off 涂层剥离

Florida Exposure



SAE
J2527

ASTM
D7869



Expected Failure Mode: Slight BC/E-coat pick off

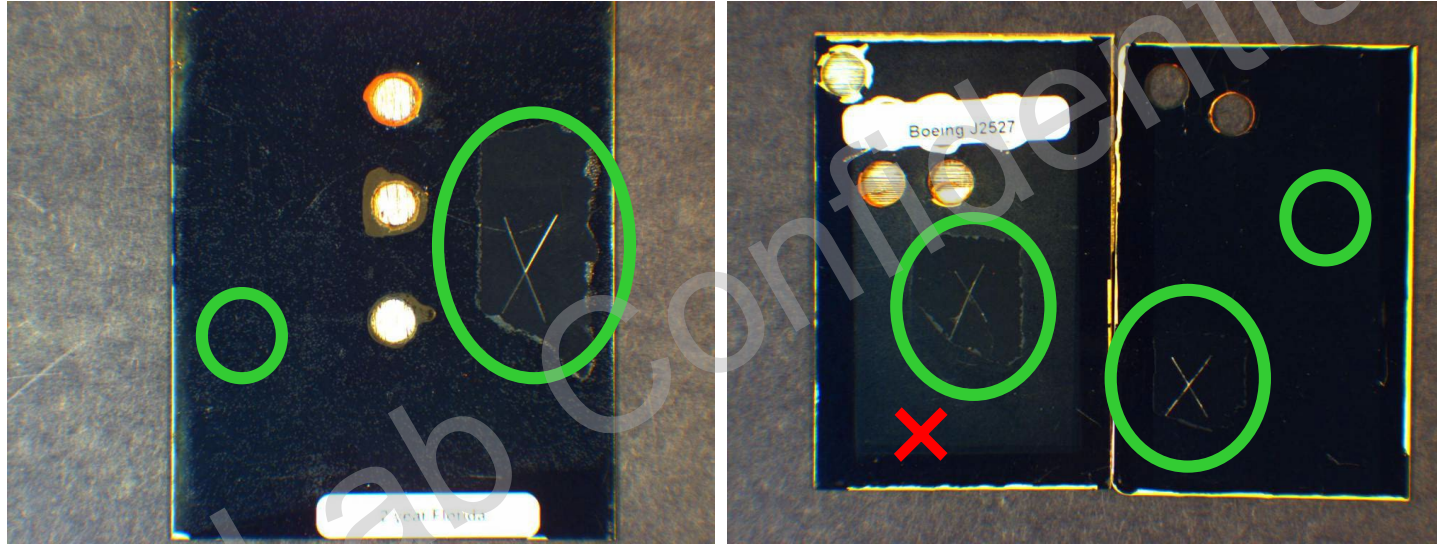
Observed: Slight BC/E-coat pick-off ASTM D7869, not SAE J2527

Gloss and Adhesion Loss 光泽和附着力损失

Florida Exposure

SAE
J2527

ASTM
D7869



Expected Failure Mode: Blistering, gloss loss, adhesion loss

Observed: Gloss and adhesion loss on both. Blistering ASTM D7869

Delamination 层离

Florida Exposure



SAE J2527



ASTM D7869



Expected Failure Mode: Blistering, gloss loss, adhesion loss

Observed: Gloss and adhesion loss on both. Blistering ASTM D7869

Blistering 起泡

Florida Exposure



SAE J2527



ASTM D7869



Expected Failure Mode: Blistering, gloss loss, adhesion loss

Observed: Gloss loss and adhesion loss seen on all panels. Blistering on ASTM D7869 mimics that seen in Florida

Evaluate Validation Testing 评估验证试验

Example from ASTM D7869

- Chemical change correctly reproduced
- Cracking correctly reproduced
- Blistering correctly reproduced
- Adhesion loss correctly reproduced
- Color correctly reproduced
- Gloss loss correctly reproduced

Conclusions: ASTM D7869 结论 : ASTM D7869

- ASTM D7869 accelerated lab weathering test cycle is **thoroughly researched** - uses scientific understanding of outdoor weather – light, heat, and water
- 深入研究了ASTM D7869加速实验室老化试验循环
- Test cycle **validated** by comparing to long-term outdoor weathering data of a variety of coatings systems
- 通过比较各种涂层体系的长期户外老化数据验证试验循环
- ASTM D7869 is **realistic** - it reproduces faithfully almost all physical failure mechanisms and is **40% faster** than current test method.
- ASTM D7869再现了几乎所有物理失效模式，比当前的测试方法快40%
- Introduction of this new weathering protocol allows for more rapid and accurate accelerated weathering results. These can be **correlated** with outdoor test data to give powerful information.
- 采用这种新的老化方案，可以获得更快速、更准确的加速老化结果。这些数据可以与户外测试数据相关联，以提供强有力的信息

Thank you for your attention!

Questions?

Send your inquiry to:
ssun@q-lab.com

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