Natural Outdoor Weathering Testing

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Q-Lab's Outdoor Testing Series

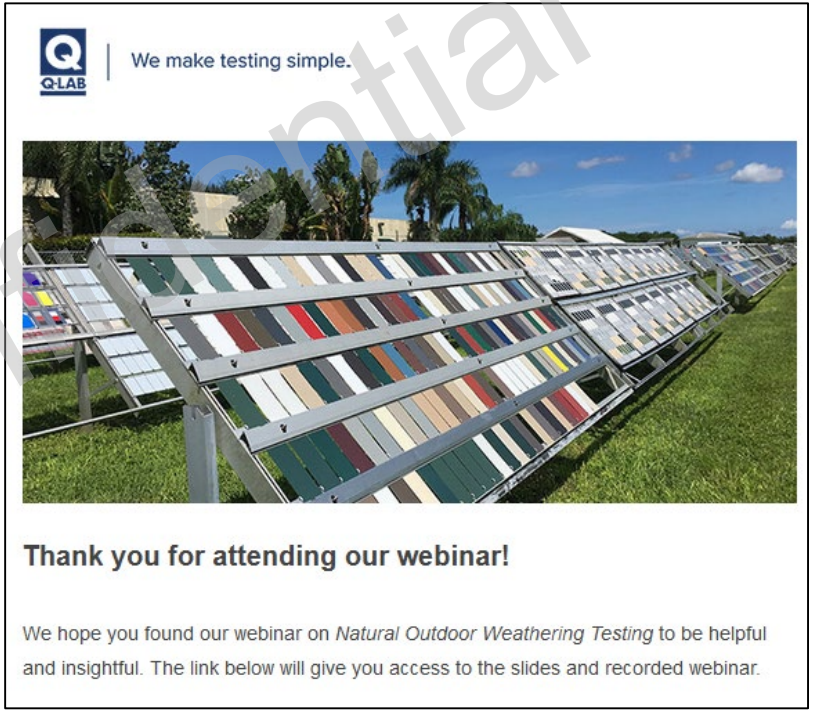
- Today is the first of a two-part webinar series on outdoor weathering test exposures
- All upcoming and archived webinars can be accessed at: q-lab.com/webinars

Date	Topic
09 Feb	Natural Outdoor Weathering
16 Feb	Accelerated Outdoor Weathering

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!



Weathering Testing

- Accelerated tests
  - Exposure in test chambers in the laboratory
  - Controlled conditions
  - Artificially-created light and simulated condensation/rain

- Outdoor Tests
  - Exposure on outdoor test racks in large fields
  - Uncontrolled conditions
  - Natural sunlight and real weather conditions

Forces of Weathering

Accelerated

- Light
- Heat
- Condensation
- Humidity
- Spray

Outdoor

- Sunlight
- Temperature
- Condensation
- Humidity
- Rain
- Biological
- Acid Deposit
- Dirt Pickup

Outdoor testing adds other weathering factors

Outdoor Weathering Myths

- Accelerated tests are 100% repeatable
  - All tests (outdoor and accelerated) have variability
- Any degradation is good
  - The wrong degradation mode can be misleading
- It takes 5 years to obtain outdoor test results
  - Outdoor testing can yield useful data in 12 months
- Weathering test data is absolute
  - A single test will not yield a perfect correlation
- Ranked data is weak data
  - Ranked data can be powerful if correctly applied
- Outdoor testing is too expensive…

Why Outdoor Testing Is Often Ignored

- Time pressures force accelerated testing for rapid results
- Many specifications, companies, and product development efforts utilize only accelerated methods believing some of the myths on the previous slide
- Ignoring outdoor testing represents a critical missed opportunity!

Why Outdoor Testing Is Important

Outdoor testing is an important and inexpensive complement to accelerated testing

- Gives confidence that degradation modes are not unintentionally changed
- Test reliability issues or experimental mistakes (human errors) can be identified
- Can give rapid, realistic results
- Establishes a working **Correlation Factor**

Outdoor Testing Costs

- Cost of Testing
  - Only $500 - $1,000 per test per year
  - Ongoing tests build a library of highly valuable data, at low cost

- Cost of *Not* Testing
  - Product recalls? Unhappy customers?
  - Less confidence in results

Global Benchmark Outdoor Exposure Locations

Florida Subtropical

Arizona Desert Sunshine

Q-Lab Outdoor Weathering Sites

Florida

Arizona

Ohio

Q-TRAC

Test sites available in many different climate types

Why Florida?

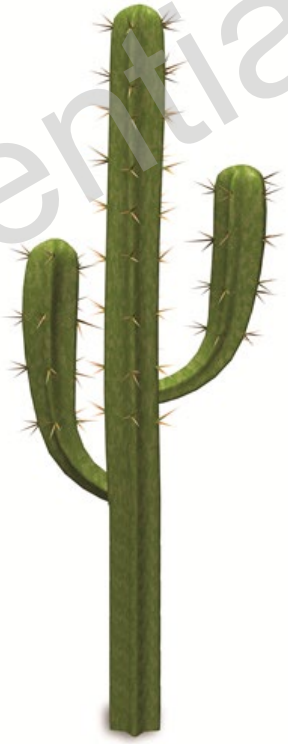
- High UV irradiance
- High temperatures
- High time of wetness (TOW)
- High humidity

Florida Is Accelerated But Not Extreme

- Same noon summer sun spectrum as temperate regions, but present in Florida for more of the year.
- Consistently hot, but max temperatures are not extreme (no 100 °F days)
- Florida's **summer** is just like summer in temperate regions
- Florida's **winter** is … also like summer in temperate regions
- *The same weather as the rest of the world, just "more of it"*

Why Arizona?

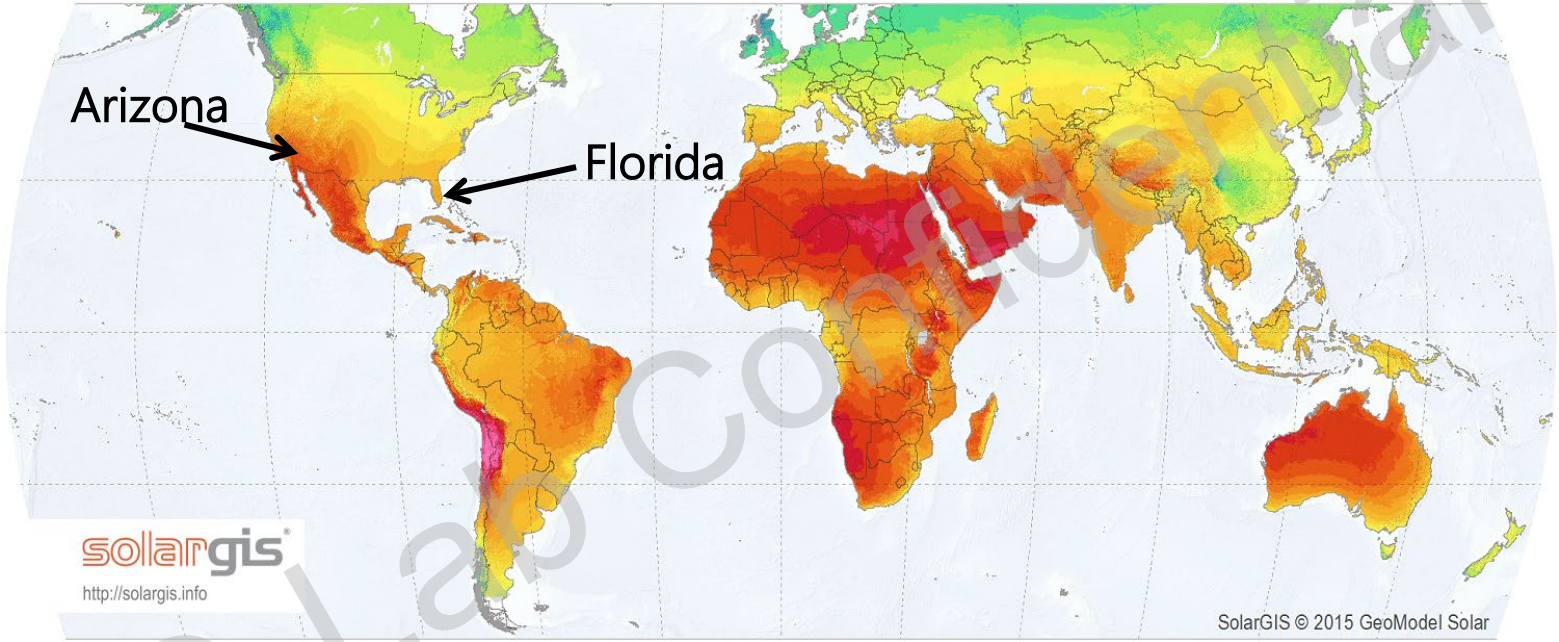
- Higher UV irradiance
- Hot, Hot, Hot!
- High temperature swings – thermal cycling
- Low moisture



Florida & Arizona Comparison

Force	Parameter		Florida	Arizona
Sunlight	Annual Solar Energy (MJ/m^2)	TUV (295-385 nm)	320	350
		Total	6588	8004
	% sunlight (from sunrise to sunset)		69	85
Heat	Summer avg. Max Temp (˚C)		32	40
	Thermal Cycling		Thermal shock from daytime thunderstorms	Large day/night temperature swings
Water	Humidity		High	Low
	Rainfall		High	Low
	Time of Wetness		High	Low

Annual Solar Energy Worldwide



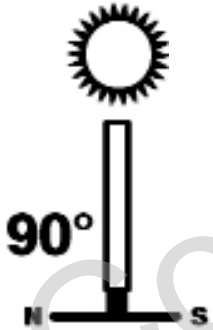
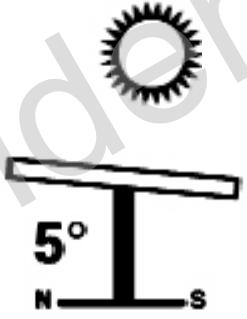
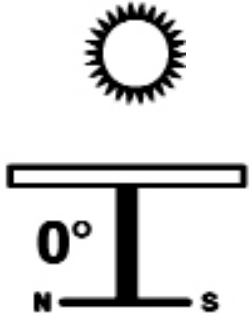
Annual Solar Radiant Energy
[GJ/m^2]

3 4 5 6 7

Natural Outdoor Exposure Variations

- Exposure Angle
- Backing
- Under-glass
- Black Box
- Mildew-enhanced
- Salt-accelerated
- Whole product

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 • Vinyl siding	• Window profiles • Wood siding • Architectural coatings	• Automotive coatings • Roofing materials	• 3D parts • Roofing •Outdoor flooring
Comment	Most commonly used outdoor exposure	Reduced solar exposure Vertical end-use	Increased wet time	Highest time of wetness

45° South Exposure Angle

90° South Exposure Angle

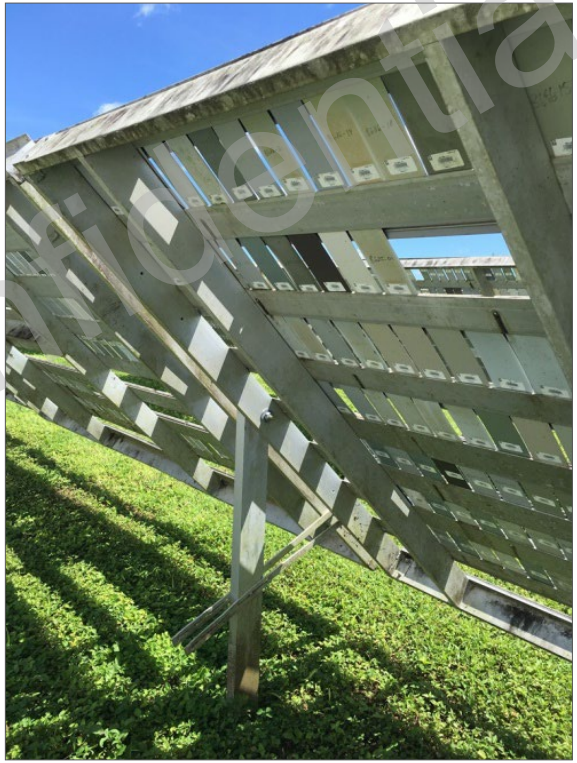
5° South Exposure Angle

0° Exposure Angle

Backing Techniques

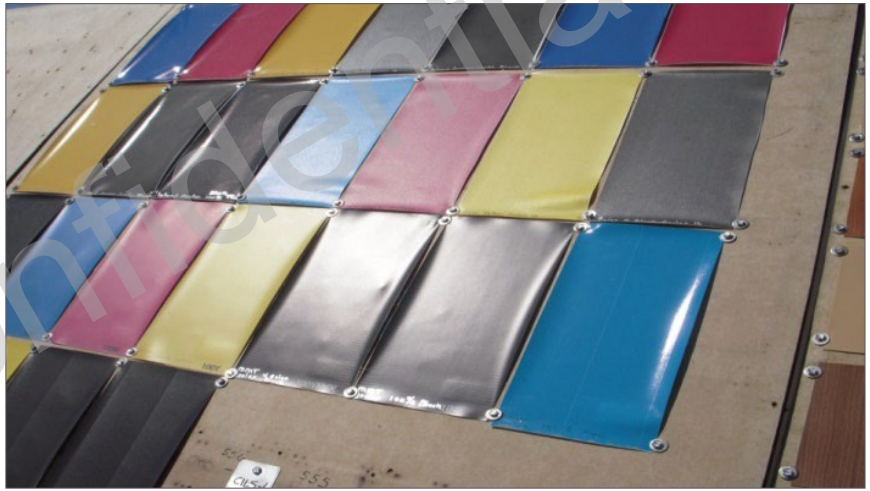
- Open-Backed
  - Used for rigid specimens
  - Painted metal
  - Plastic lenses
- Mesh-Backed
  - Flexible specimens
  - Typically for 0° exposures
- Plywood-Backed
  - Vinyl siding
  - Roofing

Open-Backed



Mesh-Backed

Plywood-Backed



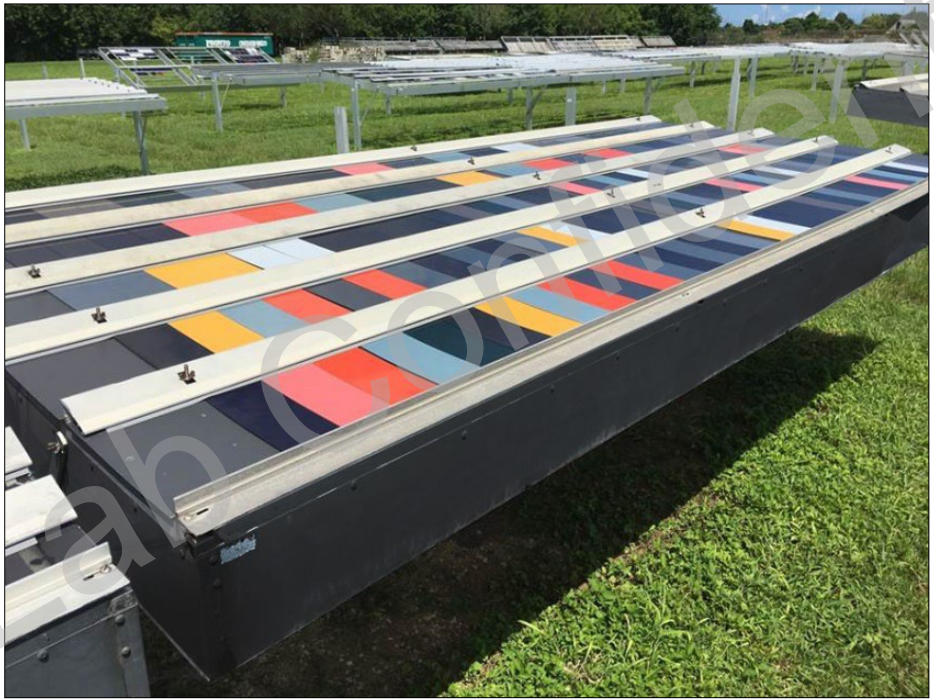
Under-Glass Exposure

Automotive Interior Testing:

Under-Glass Exposures

Automotive Exterior Testing

Black Box



Enhanced Testing

Mildew

- 90° or 45° North facing
- Mildew-enhanced area of field
- Longest time of wetness

Salt (SCAB)

- ASTM D6675 / ISO 11474
- 5% Salt Solution
- Synergistic corrosion + weathering

Whole Product

- Entire vehicle, house, etc.
- Best simulation of the end use
- All parts, materials and components interact during the weathering process
- Thermal radiation studies commonly performed

Outdoor Weathering Testing Programs

Best Practices for Outdoor Weathering Testing

- Test at benchmark sites
  - Harsh environments accelerate degradation
  - Data form these sites is internationally accepted and comparable
- Start new outdoor tests every year (or more frequently)
  - Develop library of data
  - Compare old formulations to new; compare to competitors' materials
  - Value of test data increases over time – like compound interest
- Qualify/validate your accelerated lab testing
  - Develop better laboratory tests
  - Test the lab test against real data

Best Practices for Outdoor Weathering Testing

- Begin testing as soon as possible
- Use a balanced mix of specimens
- Use at least 3 replicates
- Evaluate regularly and often
  - At least 5 intervals per test
- Use control or reference specimens
- Typically 12 to 24 months sufficient for baseline results
- Perform repeat testing and test to failure

Experimental Design for Outdoor Testing

- Every specimen type should be in every test
- Use equal number of specimens in each test
- Use regular exposure periods
  - Except it is OK to schedule more evaluations in early periods (to catch early failures)
- Use the same evaluation techniques throughout

Replicates

- More specimens lead to better data analysis, & adding them is inexpensive
  - There is unlimited “chamber capacity” for outdoor testing
- At least three replicates allows mean and standard deviation calculation
- More specimens give higher confidence that small differences in test results are truly meaningful

Reference Materials

A reference (i.e. control) material is one with known performance

- Always expose one good and one bad "control"
- Use the reference material to compare different tests or different exposures
- The results from the reference materials can be used to "normalize" the results
- This "reference" material is often not a standard polystyrene chip - it is your own material

Repeat the Tests

- The first step in writing a standard test is to prove it can be repeated
- Prove the test method is correct by doing the tests again
- Determine and measure the unknown factors that will appear when testing

Test Duration

- Durable materials need to be exposed outdoor for years – maybe 1, maybe 10, maybe 50!
  - Paint
  - Signage
  - PV modules
  - Sealants
  - Roofing materials
- Some materials require shorter outdoor exposures:
  - Food and beverages
  - Cosmetics and personal care
  - Optical lenses

Always test to failure!

Evaluation and Correlation

Degradation Modes

- Knowing the degradation modes is critical
- The degradation mode must be the same in all tests or the test may be invalid
- You must evaluate for all known degradation modes

Measurement Types

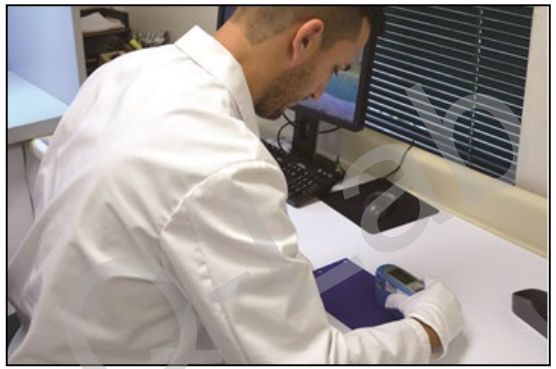
- Non-Destructive Testing
  - Reduces quantity of specimens required
  - Only gives information on surface layers
  - Can be subjective & prone to interpretation
- Destructive Testing
  - Increases quantity of specimens needed
  - Gives feedback on internal properties
  - Highly variable

Measurement Techniques

Non-Destructive

Surface Properties

- Gloss and Color
- Visual Appearance
- Surface Oxidation



Destructive

Bulk Properties

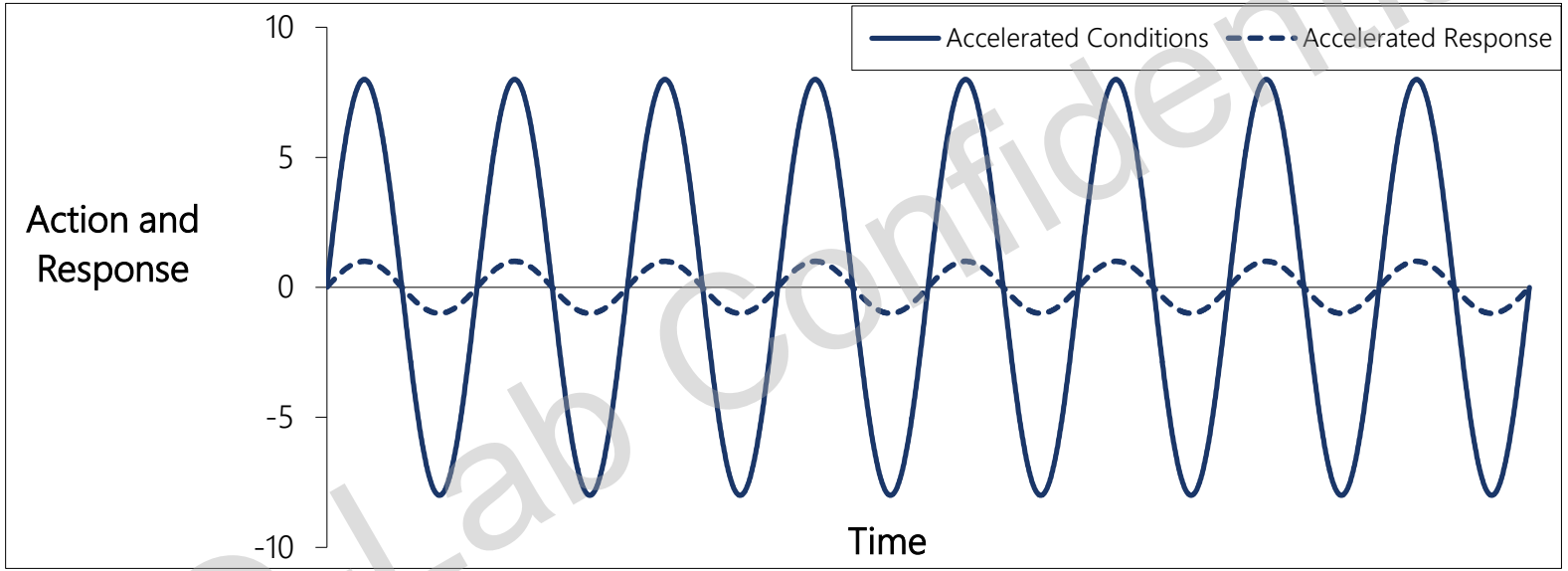
- Tensile
- Impact
- Bend
- Hardness
- Abrasion

Cyclic Conditions

	Accelerated Tests	Outdoor Tests
Average Cycle Time	2-4 hours	24 hours
Cycles per day	6-10	1 (!)
Dark period?	Maybe	Always
Cycle variation	Same every time	Different every day

Cyclic Conditions

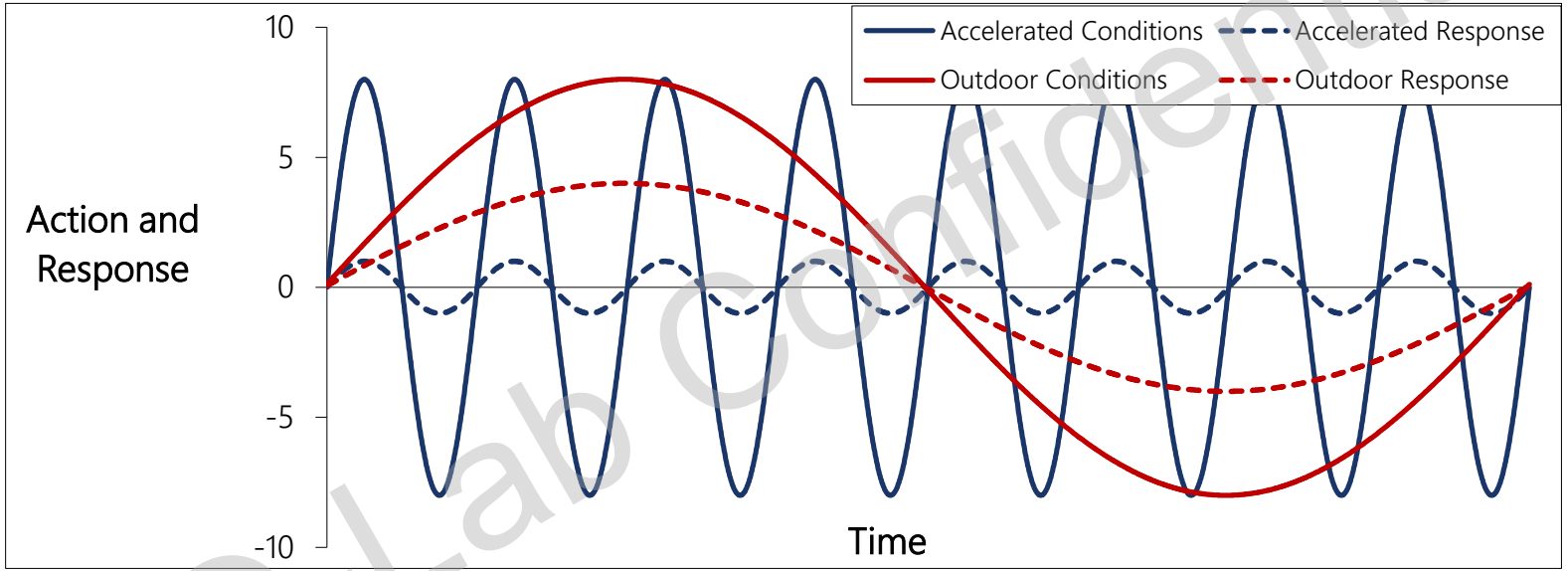
Accelerated Testing



As the environment changes, the material under test will attempt to equilibrate to it – but there is a delay in the material's response

Cyclic Conditions

Accelerated and Outdoor Testing



Different cycle times in Outdoor vs. Accelerated tests may result in different material equilibrium responses

Cycle Design Improvements

By studying the different results between the two types of tests, improvements to accelerated test cycle design can be implemented

- This helps in Correlation efforts

This opportunity becomes lost unless Outdoor testing is performed!

Correlation Factor

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

The Key to Correlation is the Outdoor Test!

Ranking Performance Data

- Use measurable targets
  - Time to 50% gloss
  - Point of greatest differentiation
  - End of test
- Calculate rank order correlation
  - Spearman correlation
  - Pearson correlation
- **Rank order correlation** can help determine if an accelerated test is a good predictor of real time

Spearman Rank Correlation

Example from Gloss Data

Specimen #	Xenon rank	Florida Rank
1	2	2
2	1	1
3	7	7
4	5	5
5	4	4
6	6	6
7	3	3

This dataset gives a Spearman Rank coefficient of 1.0

Perfect rank order correlation

Spearman Rank Correlation

Alternative Examples

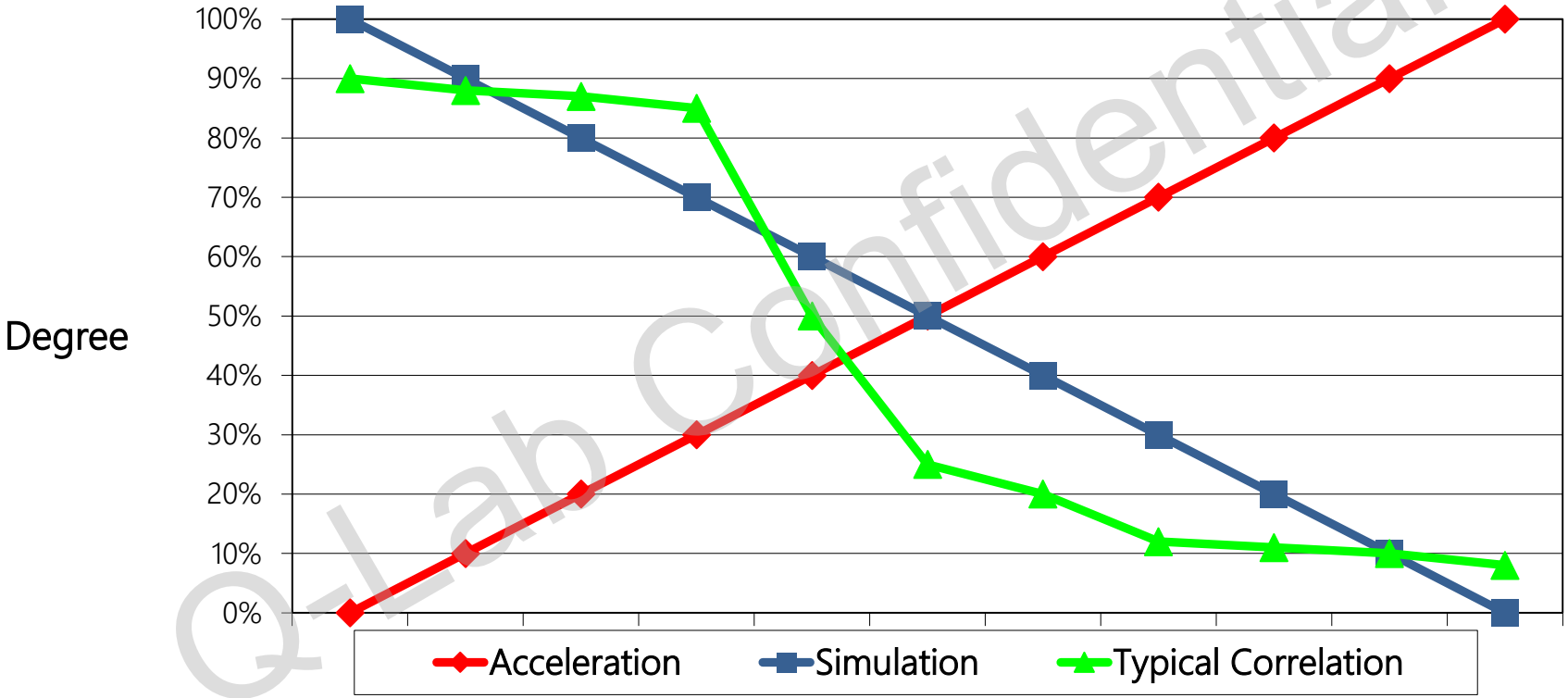
Specimen #	Xenon rank	Florida Rank
1	2	6
2	1	7
3	7	1
4	5	3
5	4	4
6	6	2
7	3	5

Spearman Rank -1.0

Specimen #	Xenon rank	Florida Rank
1	2	6
2	1	2
3	7	4
4	5	1
5	4	7
6	6	3
7	3	5

Spearman Rank ~0.0

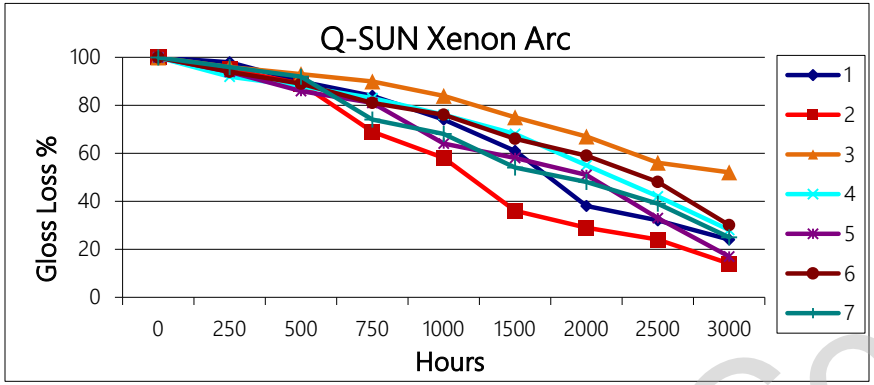
Acceleration and Correlation



Acceleration Factor

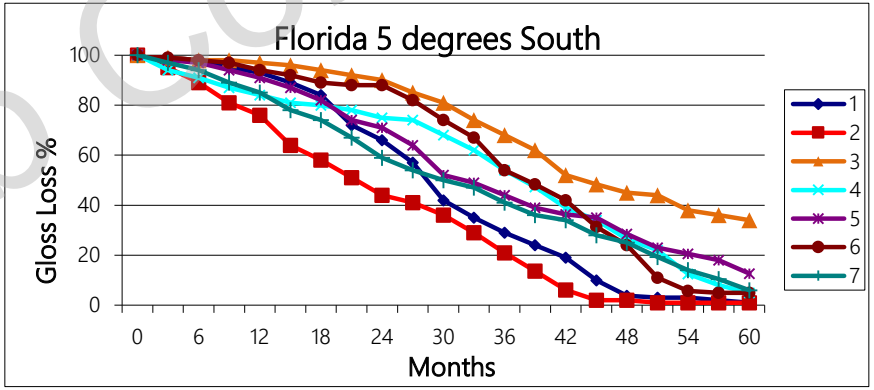
- Use Time vs. Degradation curves
- Compare the accelerated and outdoor
- Check for time to reach same amount of failure mode
- Verify by ranking or compare means
- If results are same, calculate acceleration factor (AF)
- AF = Time Outdoor / Time in Accelerated

Time Degradation Curves



Xenon Arc Exposure
50% Gloss Loss
1 = 1800 hours, Rank 2
2 = 1250 hours, Rank 1
3 = 3000 hours, Rank 7
4 = 2250 hours, Rank 5
5 = 2100 hours, Rank 4
6 = 2500 hours, Rank 6
7 = 1900 hours, Rank 3

Outdoor Florida Exposures
50% Gloss Loss
1 = 30 months, Rank 2, **AF 12:1**
2 = 24 months, Rank 1, **AF 14:1**
3 = 45 months, Rank 7, **AF 11:1**
4 = 40 months, Rank 5, **AF 13:1**
5 = 36 months, Rank 4, **AF 13:1**
6 = 42 months, Rank 6, **AF 12:1**
7 = 33 months, Rank 3, **AF 13:1**



All data fictitious. Acceleration factors cannot be transferred

Summary

Example Test Program

Outdoor

1. Florida
2. 5° South
3. 60 months duration
4. Measure at 3 months
5. Color, Gloss, Visual
6. 300 × 150 mm panels

Accelerated

1. Xenon Arc
2. Daylight Filters
3. 3,000 hours
4. Measure at 250 hrs
5. Color, Gloss, Visual
6. 75 × 50 mm panels

Expose reference panels in each test, compare the type & rate of degradation to the reference panel, and ensure the accelerated test is providing the correct results

Putting it All Together

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Conclusions

- Accelerated testing is a great way to get fast weathering results

- Outdoor testing complements and verifies accelerated testing
  - It is often overlooked, despite being inexpensive, fast, and easy to implement
  - It helps increase confidence and correlate results to real world experience

Thank you for your time.

Questions?

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