

Outdoor Weathering Must Verify Accelerated Testing

Q-Lab Corporation

Andy Francis

Dave Duecker

Bill Tobin

Sean Fowler

Q-Lab Test Services

Homestead (Miami), Florida

Buckeye (Phoenix), Arizona

Saarbrücken, Germany

Shanghai, China

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Thank you for attending our webinar!

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

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Q-Lab Test Services

Florida



Arizona



Ohio



Q-TRAC



Test sites in many different climate types

Overview

- 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

Weathering Tests

- **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



Factors of Weathering

Accelerated

- Light
- Heat
- Condensation
- Humidity
- Spray

Outdoor testing adds other weathering factors

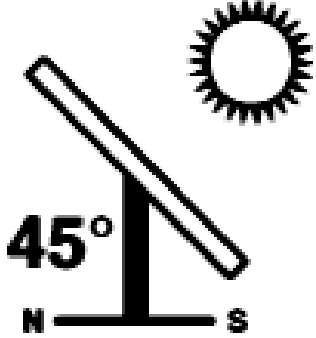
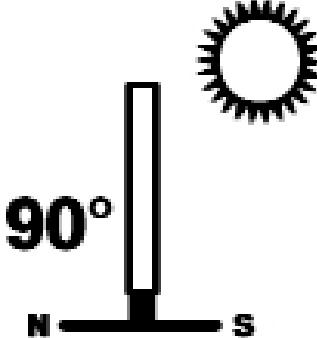
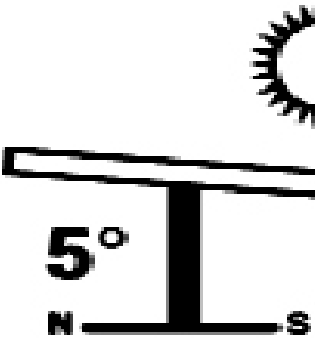
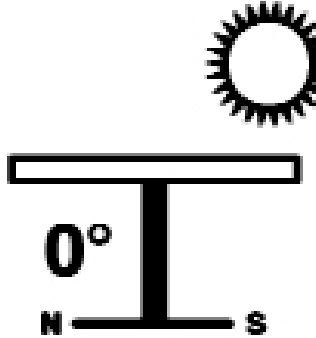






Outdoor

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

Outdoor Test Types

Exposure Angles

45° South	90° South	5° South	0°
			
			

Outdoor Test Types

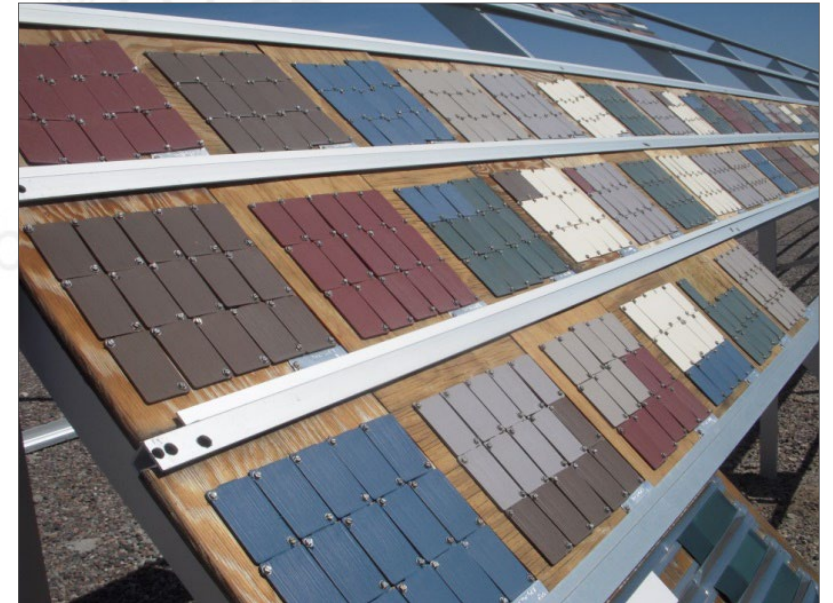
Backing Techniques



Open Back



Mesh Backed



Plywood Backed

Outdoor Test Types

Under Glass



Outdoor Test Types

Automotive Interior



Automotive Interior Materials (AIM) Box

Outdoor Test Types

Automotive Interior



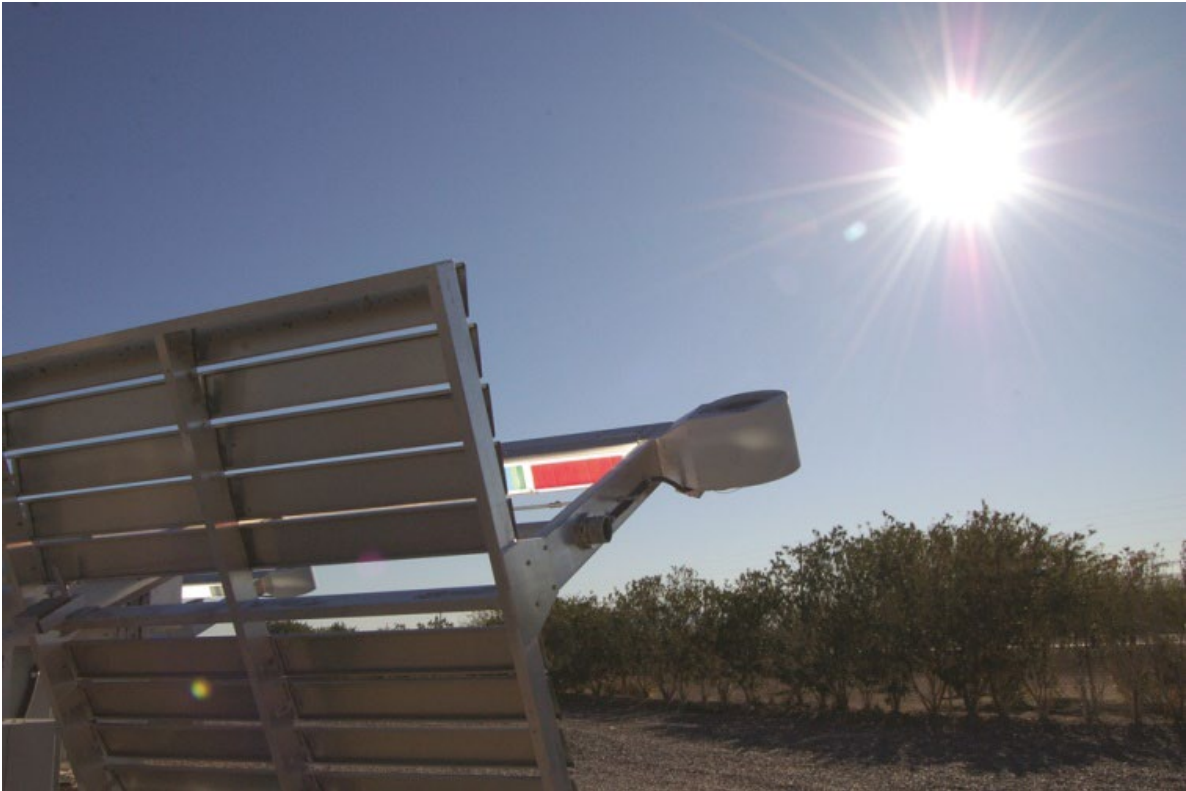
TRUE-AIM Box



Black Box

Outdoor Test Types

Natural Solar Concentrator



Q-TRAC

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...

Outdoor Testing Costs

- Cost of Testing

- Only \$500 - \$1,000 per test per year
- More confidence in results

- Cost of *Not* Testing

- Product recalls? Unhappy customers?
- Less confidence in results

The Problem

- Time pressures force rapid testing
- Many specifications, companies, and product development efforts utilize only accelerated methods, mistakenly believing that outdoor testing:
 - Takes too long to get meaningful results
 - Is too difficult to correlate
- Ignoring outdoor testing represents a critical missed opportunity!

The Solution

Outdoor testing is an important and inexpensive complement to accelerated testing

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

Correlation Factor

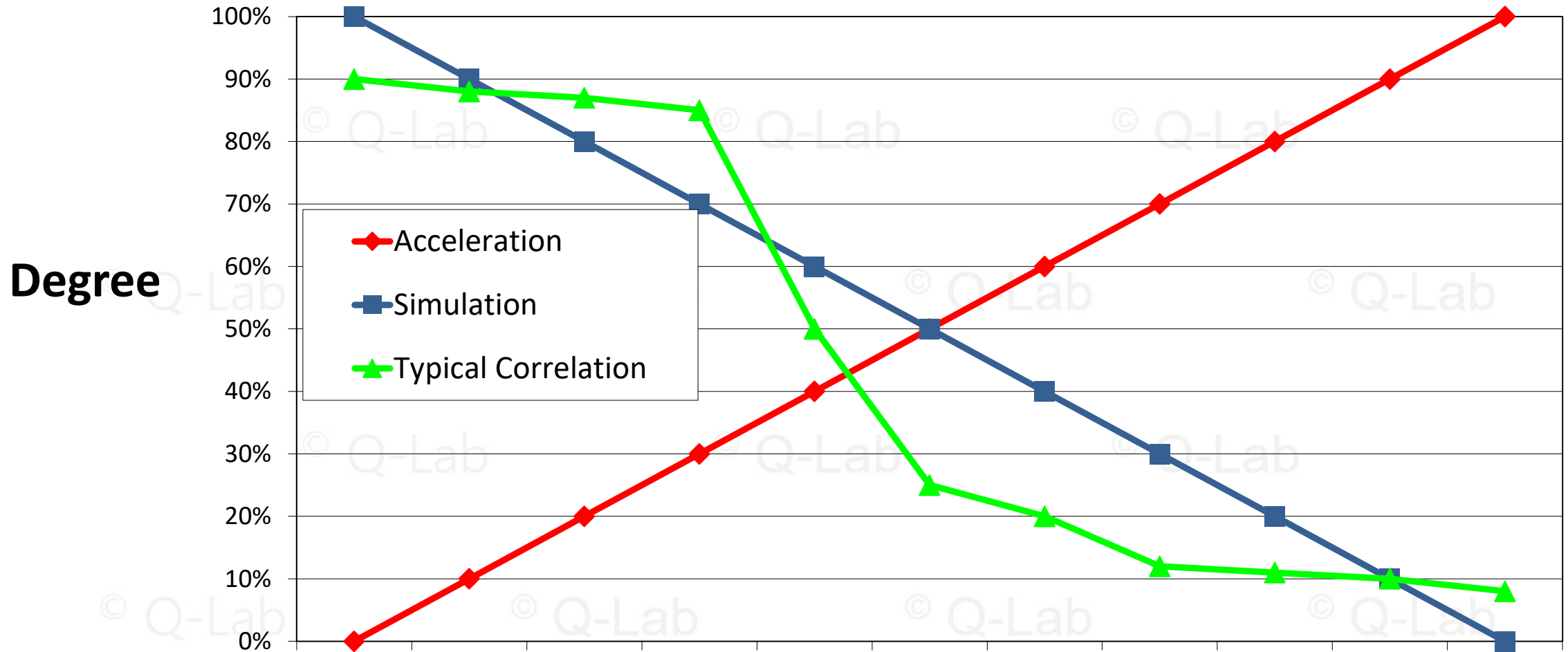
Definition of Correlation: “The agreement of results between outdoor and accelerated tests” (ASTM G113)

The Key to Correlation is the Outdoor Test!



How Much Acceleration?

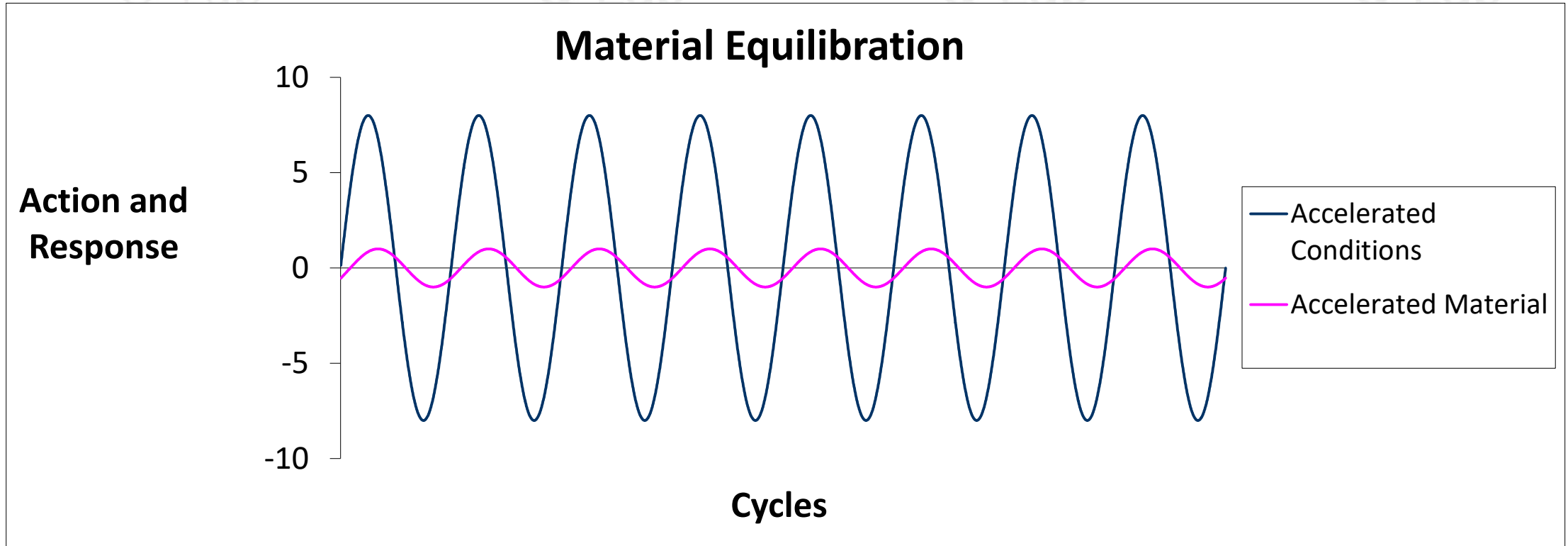
Simulation and Acceleration



Cyclic Conditions

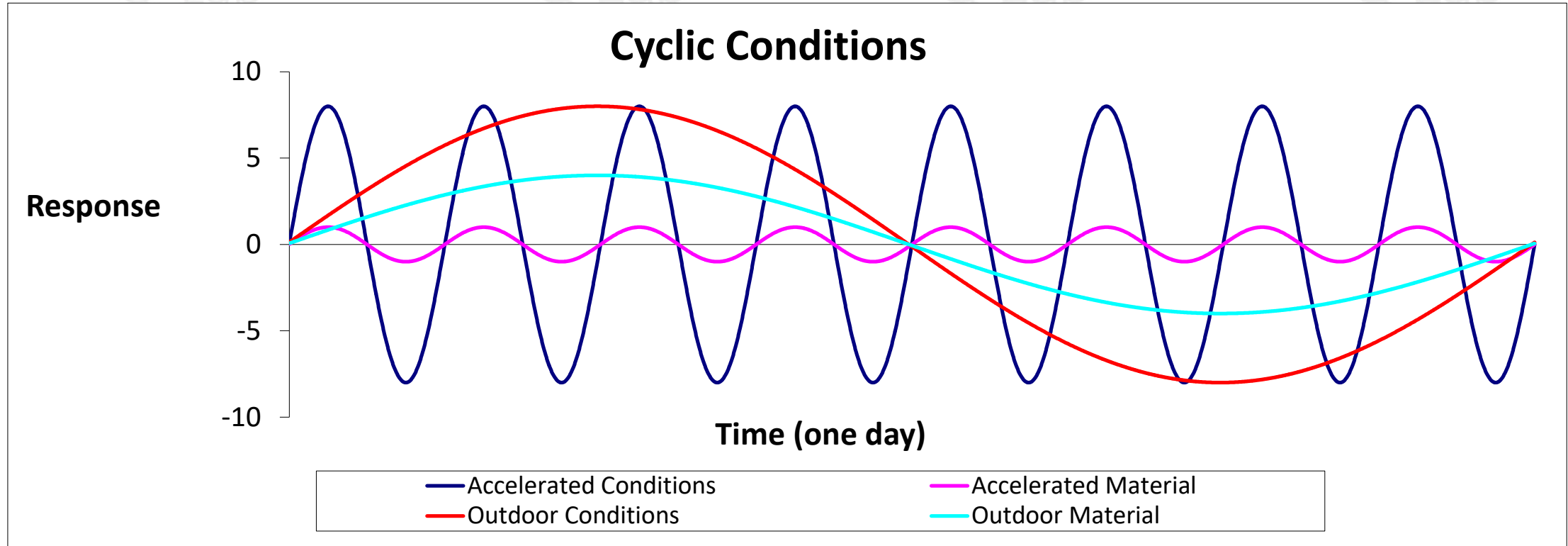
	Accelerated Tests	Outdoor Tests
Average Cycle Time	2-4 hours	24 hours
Cycles per day	6-10	1 (!)
Dark period?	Maybe	Always
Cycle variation	Same every time	Different every day

Cycle Times Compared



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

Equilibrium Comparison



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!*

Planning Your Outdoor Weathering Test

- Begin testing as soon as possible
- Use as many **replicates** as you can
- **Evaluate** regularly and often
 - At least 5 intervals per test
- Use control or **reference** specimens
- Establish a baseline
- Typically 12 to 24 months sufficient

Experimental Design

- Use a mix of different specimens
- Expose replicates
- Use reference materials
- Repeat the tests



Balanced Design

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

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

Gather the Data

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

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

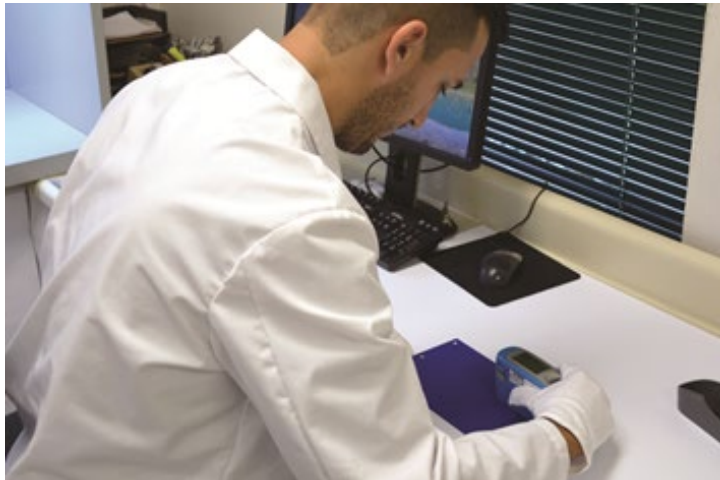


Measurement Techniques

Non-Destructive

Surface Properties

- Gloss and Color
- Visual Appearance
- Surface Oxidation



Destructive

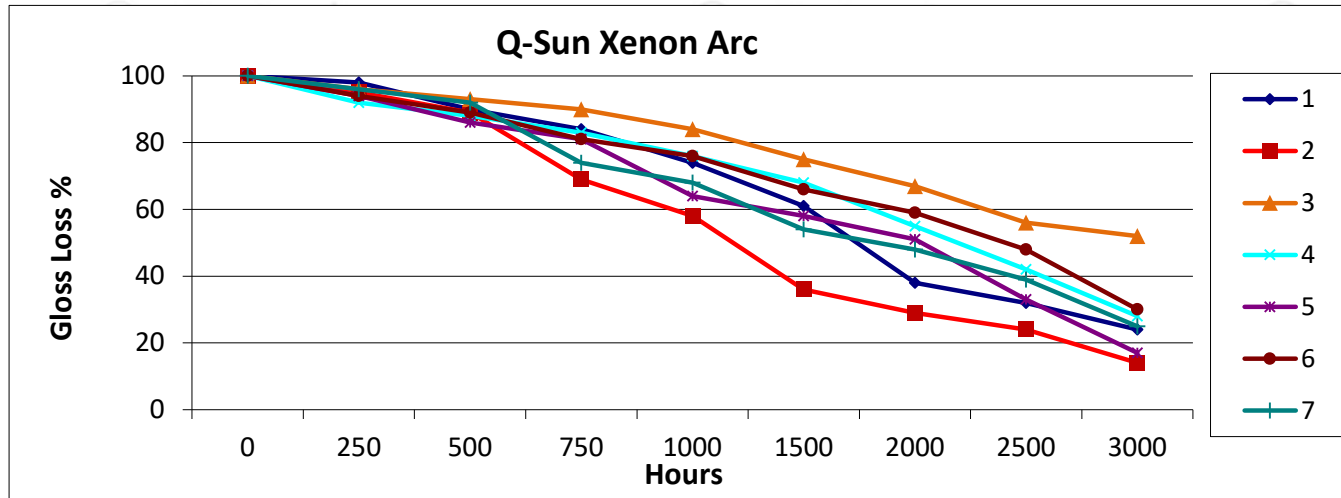
Inherent Properties

- Tensile
- Impact
- Bend
- Hardness
- Abrasion

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)
- $AF = \text{Time Outdoor} / \text{Time in Accelerated}$

Time Degradation Curves



Xenon Arc Exposure

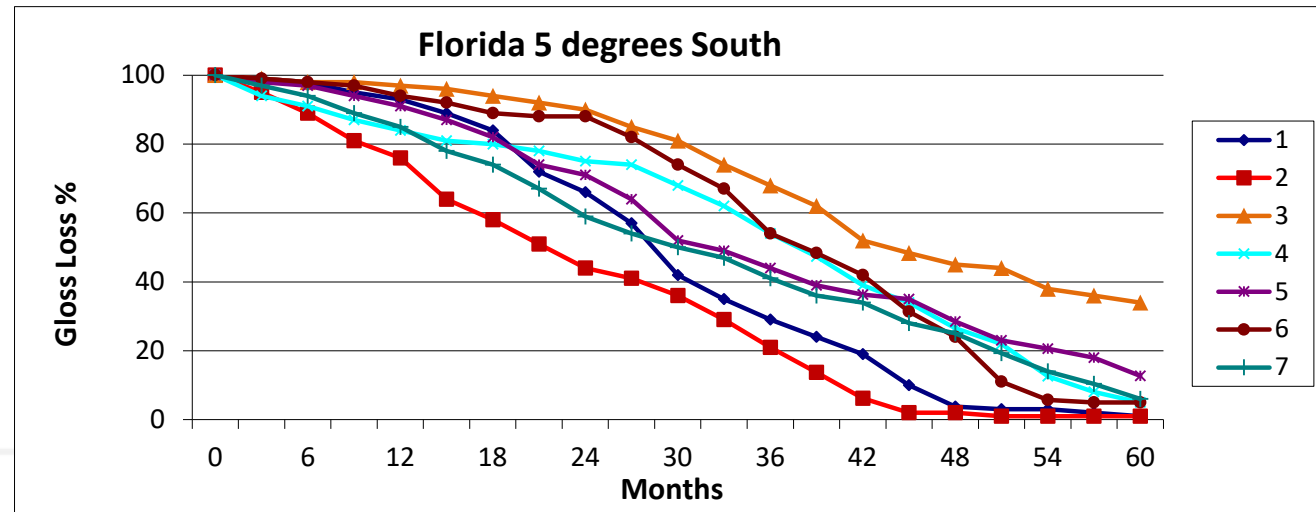
50% Gloss Loss

- 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

Statistics

- Statistical Analysis will answer ...
 - Is the test method realistic?
 - Are the test results reliable?
 - What is the acceleration factor?
- Two simple, powerful statistics
 - Comparison of Means (Student t)
 - Rank Correlation (Spearman's rho)

Comparison of Means

- Directly compare two sets of data
 - Is one test different from another?
 - Did two specimens perform differently?
- Compare experimental to production
 - Is the new product better than the old?
 - Is there a significant improvement?

Student t-Test

- Determine the two means \bar{X}_1, \bar{X}_2
- Determine the two standard deviations S_1, S_2
- Count the specimens N_1, N_2

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2} \right) \left(\frac{1}{N_1} + \frac{1}{N_2} \right)}}$$

- Independent of specimen quantity

Rank Data

- Rank specimens in order of performance
- Use measurable targets
 - Time to 50% gloss
 - Ranking at greatest differentiation
 - Ranking at end of test
- Can be used to determine if an accelerated test is a good predictor of real time

Spearman Rank Correlation

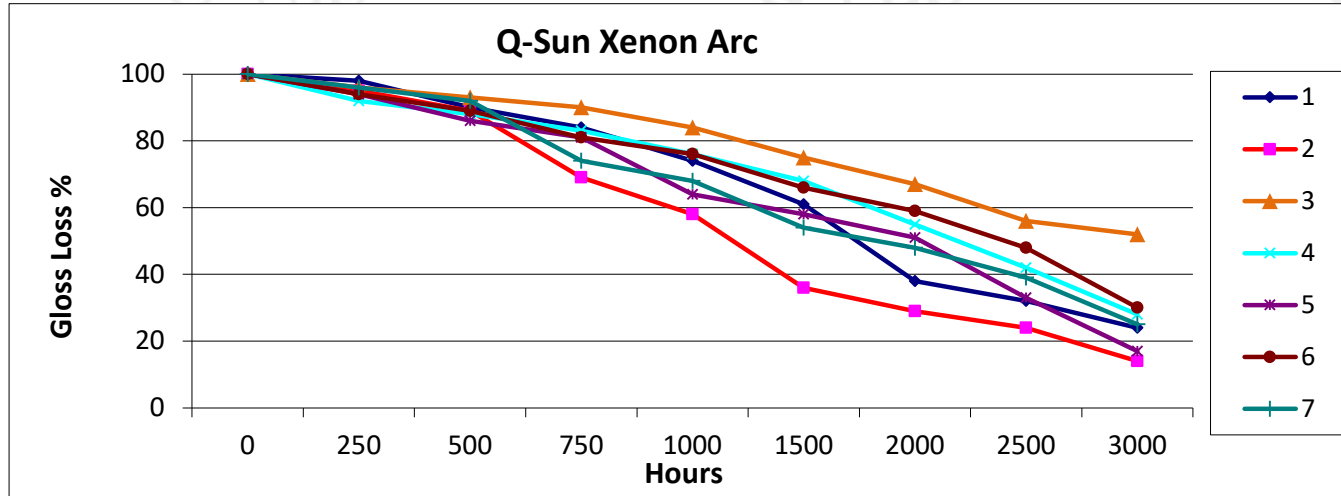
- Determine the Differences
- Sum the square of differences ΣD^2
- Count the specimens N_1, N_2

$$r_s = 1 - \frac{6(\Sigma D^2)}{N(N^2 - 1)}$$

- Ties are allowed, but must be accounted for

Spearman Rank Correlation

Example from Gloss Data



Xenon Arc Exposure

50% Gloss Loss

1 = 1800 hours, Rank 2

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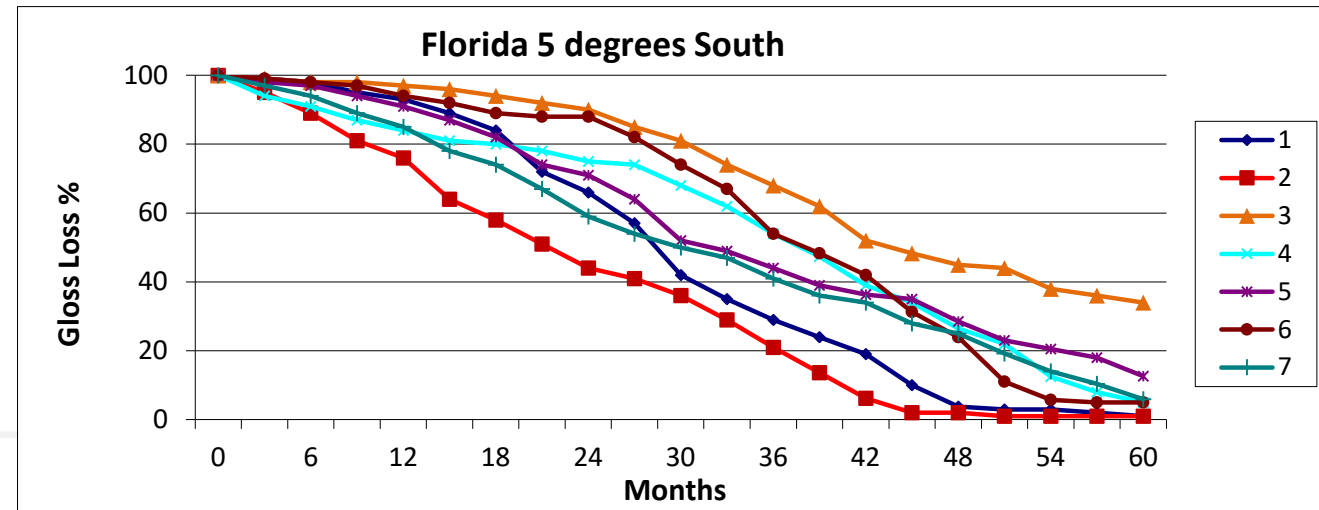
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Spearman Rank Correlation

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

Best Practice Testing

Outdoor Location

1. Hot, Wet, UV
2. Very Hot, Dry, UV
3. Temperate
4. Pollution
5. Seashore
6. Very Cold

Accelerated Test

1. Xenon
2. Fluorescent UV
3. Solar Concentrator
4. Combined UV/Salt

Pick one from Column A, one from Column B, and a real world example

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 fastest 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

References and Further Reading

ASTM

- G141 Guide to Addressing Variability
- G147 Conditioning and Handling Test Specimens
- G151 General Practice Accelerated Testing
- G169 Guide to Statistics in Weathering



www.q-lab.com

- Sunlight, UV and Accelerated Weathering
- Errors Caused by Joules
- Outdoor Weathering Exposure Procedures
- Visual Evaluations and Instruments



Questions?



info@q-lab.com