Introductions To Evaluations in Weathering Testing

Darren Assey
Sales & Technical Support
darren@thermoline.com.au
www.thermoline.com.au

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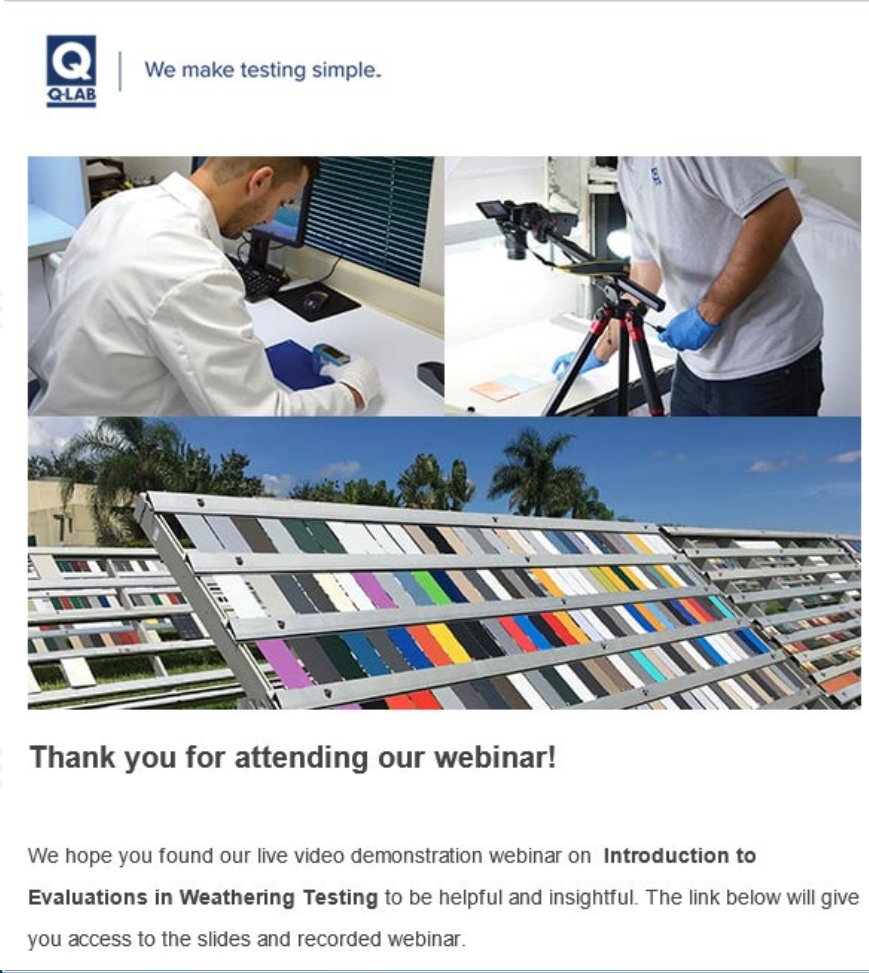


What we're going to Cover

- What are evaluations and why are they so important?
- Which are the best evaluations to choose?
- What kind of data does each evaluation provide?
  - What do those ratings or numbers mean?
- How often should you schedule evaluations?
- How can evaluations improve reliability of decisions?
- How can evaluations data best be used to make decisions?

What are “Evaluations”?

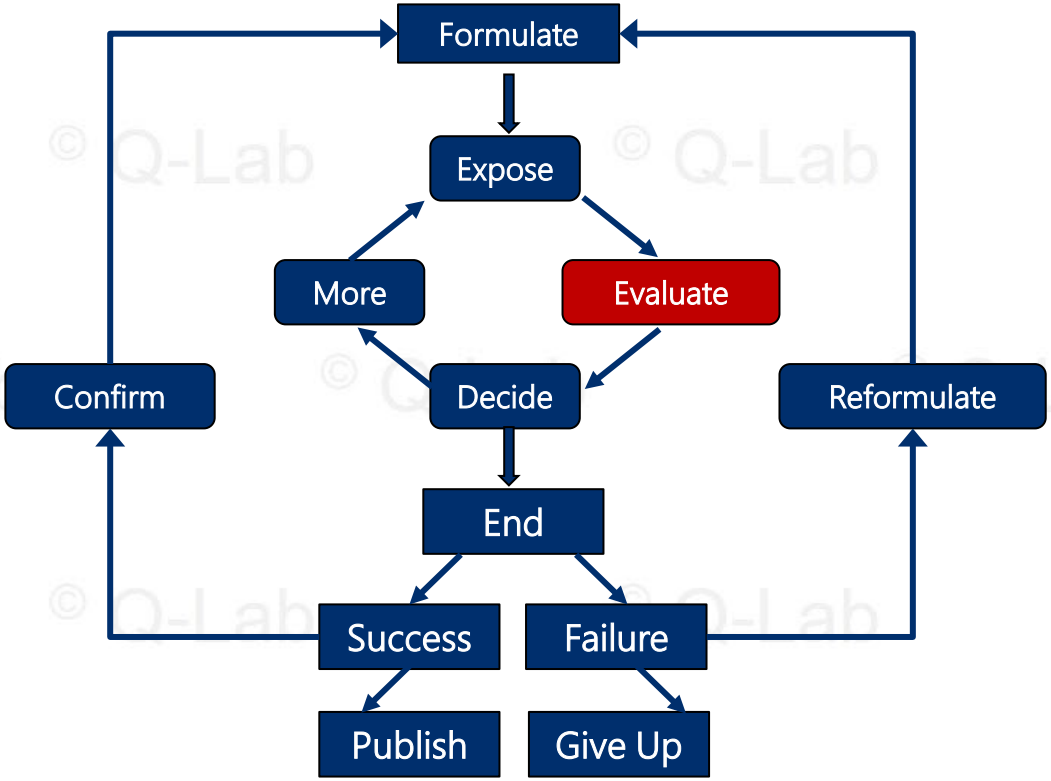
- This presentation is an “Introduction” to Evaluations
  - why they are important, which ones are best, when to do them
- **Evaluation, n:** in weathering, refers to any method used to assess the condition or performance of a specimen before, during, or after an exposure period.
  - Sometimes also known as …Inspection, measurement, report, status update, visual
  - More details on the specific evaluation techniques we touch on here are part of other presentations in the Q-Lab series.

Why are Evaluations so Important?

- Evaluations are a vital part of any durability test program
- Determine whether the testing was successful
- Exposures alone do not provide any results
- Values from evaluations or measurements are the “result”

Production workflow

Evaluations are integrated into a successful product development and testing program



Evaluations Lead to Decisions

- Evaluations
  - Produce Results
  - Create Data
  - Provide Evidence
  - ALWAYS use statistical tools
- Decisions
  - Pass or Fail
  - Better or Worse
  - Make or Break
  - Stop or Go
  - More or Less

What Evaluations are available?

- Non-Destructive
  - Same specimens can go back for more exposure
  - Fewer specimens required
    - Best for lab tests
    - No problem outdoors
  - Only yields surface data
  - Impression that data is not robust
    - Not true of course
- Destructive
  - Specimens cannot be returned to exposure
  - Different specimens for each duration
    - Adds specimen variability
  - More specimens required
    - OK for outdoor testing
  - Gives information on physical properties
  - Sometimes only way to get relevant data

Which Evaluation is Best?

- The best evaluation is the one that is done
  - Affordable
    - If cost is the prohibitive factor, find a ~~cheaper~~ alternative instead of cutting back on evaluations
  - Gets the most relevant information
    - Use your budget to evaluate for the most critical failure modes
    - But make sure nothing is omitted

Common Evaluations

- Non-Destructive
  - Visual (Subjective)
    - Surface defects, including rust
  - Instrumental (Objective)
    - Color, Gloss, D of I
  - Analytical*
    - FTIR, X-Ray, SEM
- Destructive (Objective)
  - Destroys Entire Specimen
    - Impact, Bend, Tensile
  - Damages Part of Specimen
    - Hardness, Adhesion

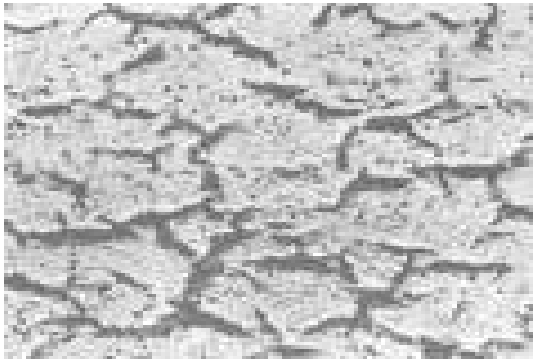
**** Not normally done in weathering labs, but common in some research labs***

Visual Evaluations

- An individual reviews the specimens for any signs of degradation and then identifies and rates it
  - Subjective
  - Large variability
  - Bias?
  - Easy to perform
  - Inexpensive
  - Specimens available at the end of the test
    - Important to archive specimens
- Training & verification reduce variability and bias
- Follow standards with defined procedures and rating scales

Failure Modes for Visual

Effect	Standard
Adhesion	ASTM D3359, ISO 2409
Blistering	ASTM D714, ISO 4628-2
Chalking	ASTM D4214, ISO 4628-7
Checking/Cracking	ASTM D660 / D661, ISO 4628-4
Color (visual)	ASTM D1729, ISO 3668
Corrosion	ASTM D1654, ISO 4628-8 & ISO 4628-10
Dirt	ASTM D3274
Erosion	ASTM D662
Flaking	ASTM D772, ISO 4628-5
Instrumental Gloss	ASTM D523, ISO 2813
Mildew Growth	ASTM D3274
Surface Rust	ASTM D610, ISO 4628-3



What do those rating scales mean?

Numerical Scales

Numerical scales are used to depict the degree of effect being reported.

Quality	Change	ASTM	ISO	AATCC
Excellent	No Effect	10	0	5
----	Very Slight	9	1	4-5
Very Good	Slight	8	2	4
Good	Moderate	6	3	3
Fair	Pronounced	4	4	2
Poor	Severe	2	5	1
Very Poor	Very Severe	0	-	-

These scales are used for a wide variety of defects included in test reports such as: general appearance, chalk, dirt, mildew, color, etc. Odd numbers are used when the degree is obviously intermediate.

Surface Rust *(ASTM D610, ISO 4628-3)*

Indication of surface rust, based upon corrosion as a % of the surface.

ASTM Scale						ISO Scale			
10	0.01%	7	0.3%	3	17%	0	0%	3	1%
9	0.03%	6	1%	2	33%	1	0.05%	4	8%
8	0.1%	5	3%	1	50%	2	0.5%	5	40-50%
		4	10%	0	>50%				

Calculations of Color Change.

Color change is calculated as the difference in the L a b values before and after exposure. The term "delta" (Δ) is used to denote the difference. Therefore Δ = current measurement - original measurement. The larger the Δ number, the larger the color change. Thus ΔL is the change in the Lightness Factor. Δa is the change in red/green and Δb the change in blue/yellow.

(+) ΔL means there has been a lightening of the color
(-) ΔL means there has been a darkening of the color
(+) Δa means more red (or less green)
(-) Δa means more green (or less red)
(+) Δb means more yellow (or less blue)
(-) Δb means more blue (or less yellow)

A total color change value of delta E (ΔE) is calculated as composite of all three factors and is widely used as pass-fail criteria for exposed materials.

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

Instrumental Appearance Measurements

- Using an instrument to give an objective rating to a visual change
  - Instrumental Color and Instrumental Gloss best examples
- An optical device reads a surface appearance "property"
  - "Light" hits the surface and a receptor measures the amount and make-up of the "light" passing through or reflecting off the specimen
- Results are continuous values
- Results are unbiased

Gloss and Color are Most Often Used

- Gloss
  - Three angles
    - 60° for mid range
    - 20° for high gloss
    - 85° for low gloss
  - Gloss Retention is %
  - Gloss Loss is Original minus Present $\Delta = O - P$
- Color
  - CIE or Hunter
  - Scales Lch, Lab, Yxy, XYZ
  - Illuminant D65, C
  - Observer 10°, 2°
  - Specular Component in, out
  - $\Delta E = \sqrt{(\Delta L_2) + (\Delta a_2) + (\Delta b_2)}$

Wash or not Wash?

- Some surface appearance evaluations require washing first, esp. color and gloss
- Washing methods
  - Rinse (Flush)
  - Water only wiping
  - Soap and Water

Washing Recommendations

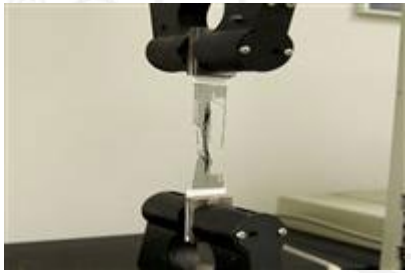
Use washing to clean off the dirt when the property requires it

- Washed
  - Color
  - Gloss
  - Cracking, checking
  - Physical tests
- Unwashed
  - Dirt and Mold pickup
  - Chalking

Washing exposes the surface more, removes some surface materials, and can increase degradation rate

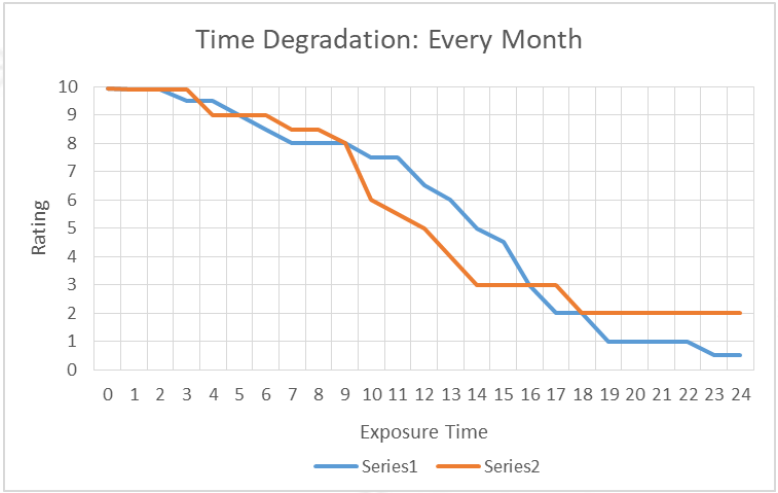
Mechanical Tests (Physical)

- Destructive (partial or whole)
  - Hardness
  - Impact
  - Bend
  - Abrasion
  - Tensile
  - Scribe Rust
- Specimens cannot go back on exposure

Frequency of Evaluations

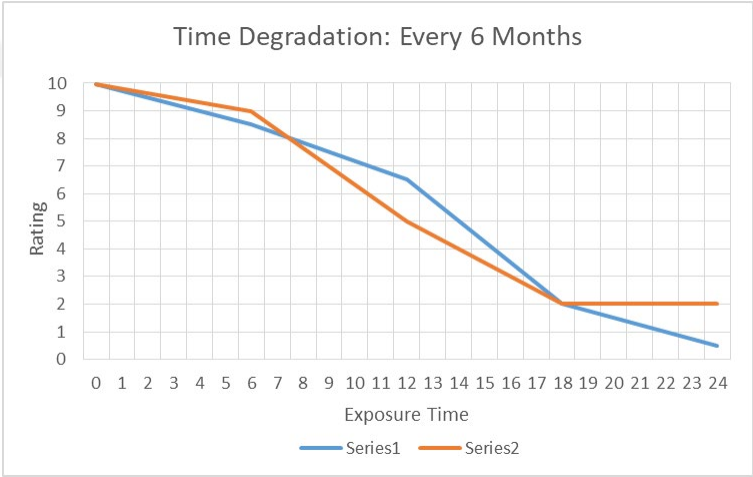
- What is the best frequency for evaluations?
  - As many as practical
  - Too few - miss inflection points
  - Too many - interruptions
- Depends on other factors
  - How complicated is the evaluation?
  - Budgetary concerns might limit choices



monthly evaluations

How many Evaluations

- Based on the recommendations from the previous slide
  - Minimum of 5 points on the graph
  - Initial, 3 Intermediate, and Final
- Examples
  - 6 months exposure: every month
  - 12 months exposure: every 3 months
  - 24 months exposure: every 6 months
  - 5 years exposure: every 12 months



6 month evaluations

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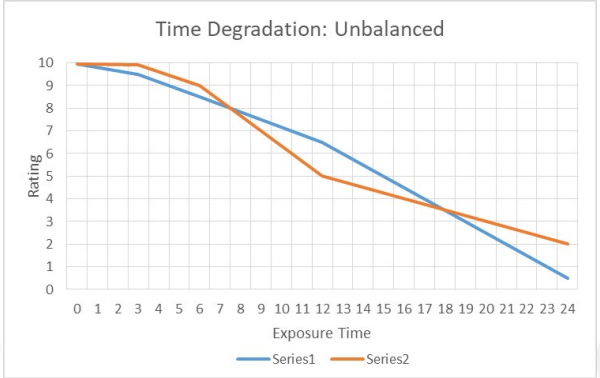
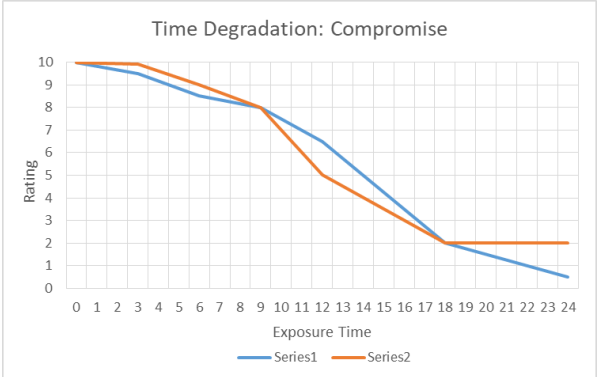
Unbalanced Schedule

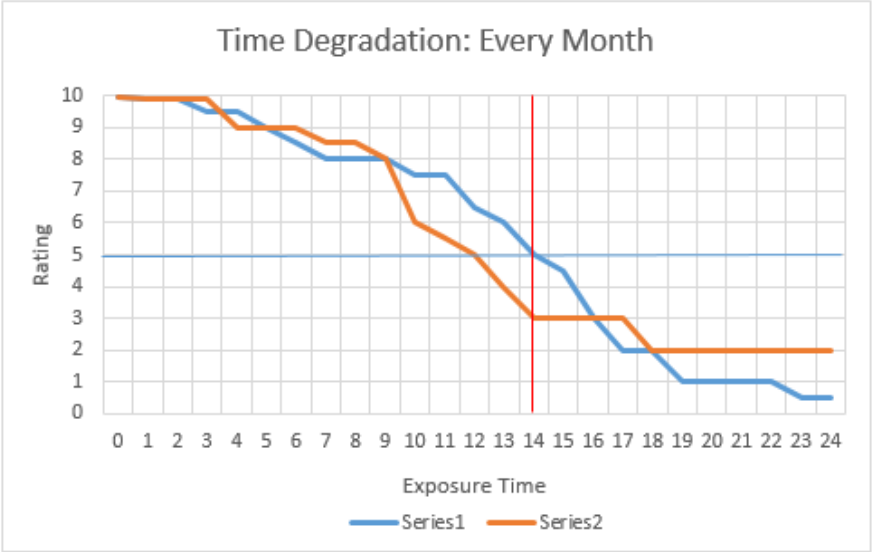
- Another option is to “front load” the schedule
  - Move evaluations earlier
  - Don’t want to miss the first change
  - Example 24 month exposure
    - 0, 3, 6, 12, 24 months evaluations
    - Always possible to add more if needed. For example 9 and 18 months if 6 and 12 months evaluation indicates it would be a good idea
  - Now we get the inflection point





Shortened Exposure Time

- Frequent Evaluations can save time and money
- Stop the exposure as soon as the end point is reached
- Future scheduled actions can be canceled if deemed unnecessary
  - Example: test scheduled for 2 years reaches end point after 14 months.
- End test with no $ penalty and X time saved!



When the last specimen reaches critical failure point

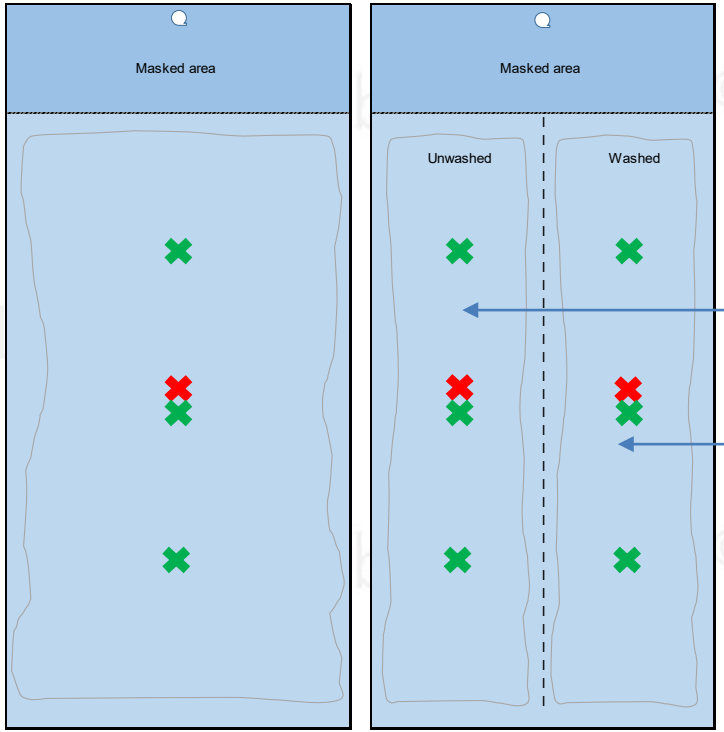
Sampling

- Which part of the specimen should be inspected?
  - **Entire specimen** for visual inspections
  - Generally, **near the center** of the area being investigated for instrumental
  - Unless there is an obvious objection (avoid) such as a scratch

- What about multiple measurements?
  - Take 3 measurements, either move, rotate, reverse
  - Chose area either by Random, Pre-Selective, Same, Different, Average ….

- Where do I look for any defects?
  - **Everywhere**
  - Sometimes we ignore edge effects (edge corrosion, dirt, algae…)

Where on the Specimen?



Visually compare color, gloss to the “original” mask area

Check unwashed side for chalk, dirt, mildew

Check washed side for cracking, rust, blistering, erosion

Location for multiple readings

Location for a single reading

Area to check for other effects

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File Specimens

- Definition: Replicate specimens that are not exposed
  - Can be used to compare degradation levels and rates.
  - Stored indoors under room temperature conditions, no light
- Best when making final determination, but
- Not necessary for interval ratings
  - Except for visual appearance when no mask area is available

What do I do with my Evaluations Data?

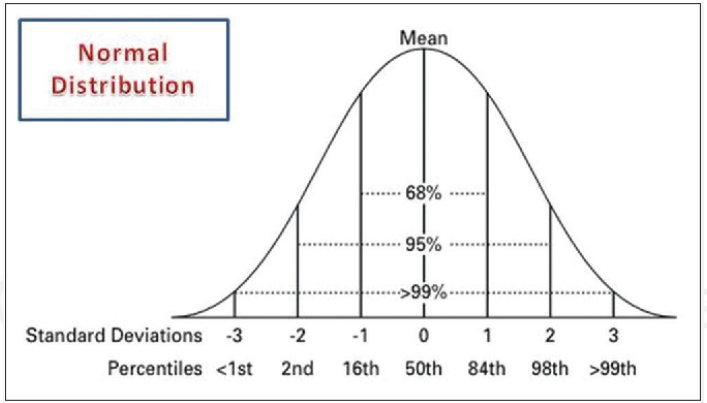
- Review it as soon as you get it
- Plot a time degradation curve
- Compare to previous experiments
- Cross check all evaluations for differences in failure rates
- Normalize to the performance of the control specimen
- Save it! Archive indefinitely, or as long as possible

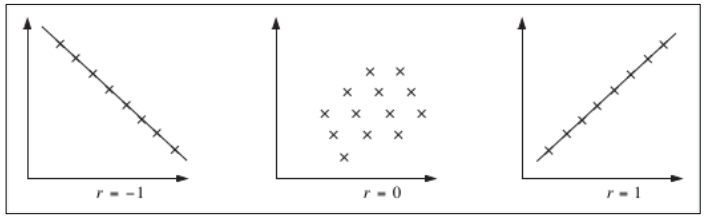
Uncertainty

- **Weathering** has a high inherent variability
- **Evaluations** have variability
- **Specimens** have variability
- Overall we have Uncertainty[3]
- Important to reduce variability as much as we can
  - Use the exact same specimens throughout the test
  - Take multiple readings or measurements
  - For lab tests, run all specimens in same chamber
  - Run all outdoor tests at same time, no capacity restrictions
  - ALWAYS use a control (or reference) specimen

Analysis of Data

- Use evaluation data to make comparisons
- Use a known reference for **accuracy**
  - Can also help "normalize" your results
- Use more specimens for better **precision**
  - Mean, Median, Range, Standard Deviation
- Use simple Statistics to make decisions
  - t-Test best for single comparisons
  - Rank correlation for test method comparisons
- Complex **Service Life Prediction** models not necessary





What does my Data tell me?

- Be careful to draw the correct conclusions from the data
- Don't be fooled by "non-significant" differences
  - Especially small delta E color (<1.0) or delta gloss values (<2.0)
- *Comparative data* tells you one is better than the other
  - Or that there is no real difference
- *Absolute data* tells you whether it's a pass or a fail
- *Ranked data* tells you if one test is the same as another

Want to Know More?

- Obtain **ISO 4628** *Evaluation of degradation of* coatings, Parts 1-8, 10
- Read **ASTM G169** *Guide to Basic Statistics for Weathering Results*
- Review our Q-Lab "Legend" for visual and for color scales primers
- Learn color and gloss from one of the equipment manufacturers

Final Thoughts

- Don’t economize by eliminating evaluations
  - Only get what you need but don’t skimp on content or frequency
- Schedules can be revised, either shorter or longer
- Use evaluation data in real time to track progress
  - Don’t let the results sit for review until test is finished
- Use statistics to make your decisions

Thank you for your time.

Questions?

darren@thermoline.com.au

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