Visual and Colorimetric Assessments of Architectural Coatings

Dave Duecker – Technical Marketing Specialist
Bill Tobin – Sr. Technical Marketing Specialist
Sean Fowler – Sr. Technical Director
Andy Francis – Marketing Director

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Click here to view the afternoon presentation.

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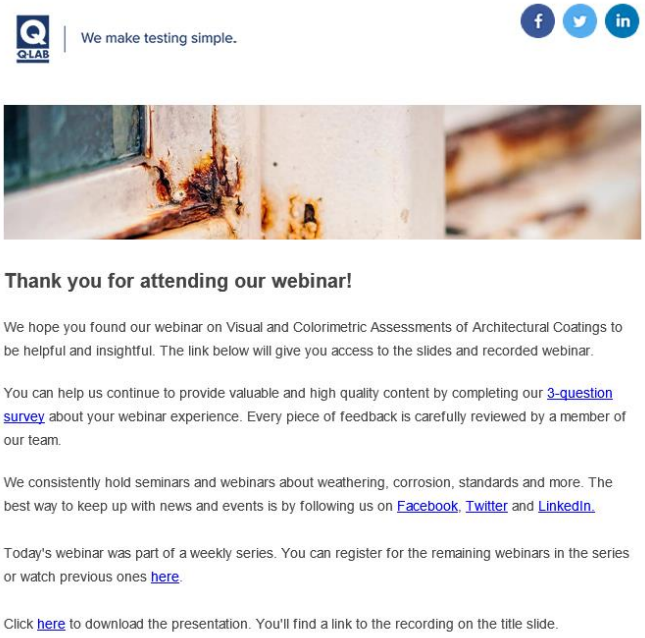

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Thank you for attending our webinar!

We hope you found our webinar on Visual and Colorimetric Assessments of Architectural Coatings to be helpful and insightful. The link below will give you access to the slides and recorded webinar.

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We consistently hold seminars and webinars about weathering, corrosion, standards and more. The best way to keep up with news and events is by following us on Facebook, Twitter and LinkedIn.

Today's webinar was part of a weekly series. You can register for the remaining webinars in the series or watch previous ones here.

Click here to download the presentation. You'll find a link to the recording on the title slide.

Overview

- Weathering Application
  - American Architectural Manufacturers Association (AAMA) coatings performance
  - Florida Exposure & ASTM G90
- Introduction to Color
  - Hunter LAB versus CIE L*a*b*
  - Color difference, ΔE
- American Architectural Manufacturers Association (AAMA) Study
  - Instrumental color changes
  - Human-perceived color
  - Correlation

Weathering and Color Change

The Fenestration Industry

- Fenestration is the collective term describing building components comprising windows and doors.
- American Architectural Manufacturers Association, AAMA, is an association of manufacturers and industry experts that represents the fenestration market.
- AAMA provides several different services, notably certifications and performance standards
- As of 2020, AAMA is now known as the Fenestration and Glazing Industry Alliance, FGIA.

AAMA Voluntary Performance Requirements

- AAMA Performance Requirements of superior products with Organic Coatings
  - **AAMA 615**, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Plastic Profiles
  - **AAMA 625**, Performance Requirements and Test Procedures for Superior Performance Organic Coatings on Fiber Reinforced Thermoset Profiles
  - **AAMA 2605**, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels

AAMA Voluntary Performance Requirements

- Each performance requirement specifies a minimum duration of outdoor Florida exposure.
- Additionally, AAMA performance requirements for fiber reinforced thermoset plastics - AAMA 623, 624, & 625 - allow for outdoor accelerated exposure by way of solar concentrator (ASTM G90)
- Coatings are to retain their color within $\boldsymbol{5\ \Delta E_H}$ through entire exposure.

Florida Exposure

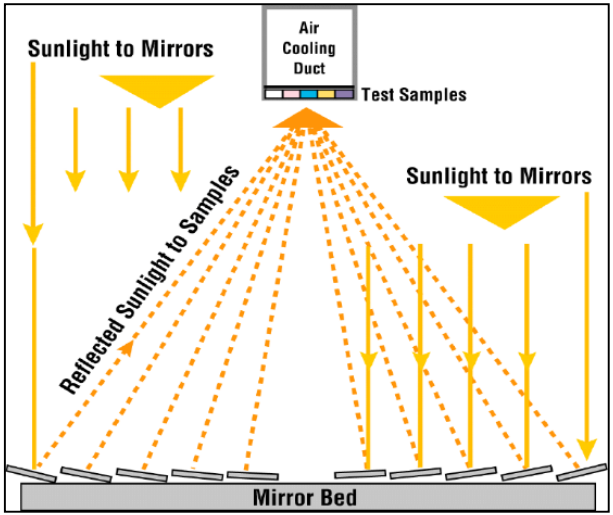
- High UV irradiance
- High temperatures
- High time of wetness (TOW)
- High humidity

45° South Florida Exposure

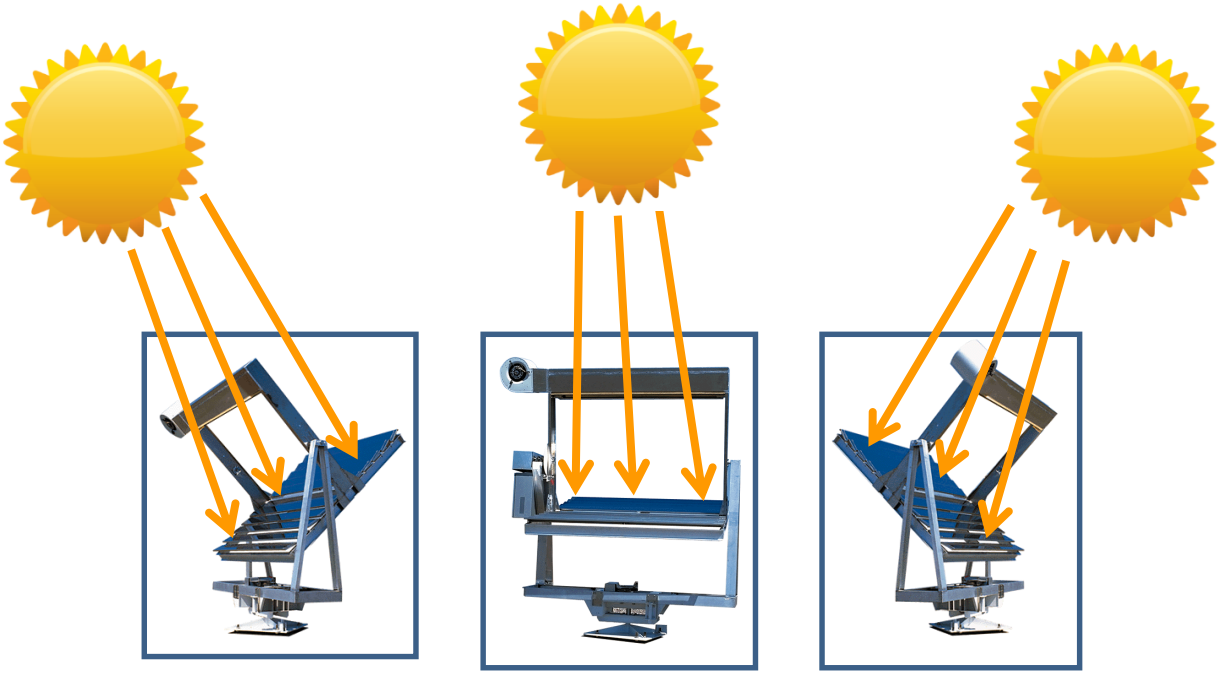
	45° South
Graphic	
Orientation	Faces Equator (north in southern hemisphere)
Duration	Standard Performance - 1-2 years High Performance - 5 years Superior Performance - 10 years
Comment	Most commonly used outdoor exposure

Natural Solar Concentrator Exposure ASTM G90

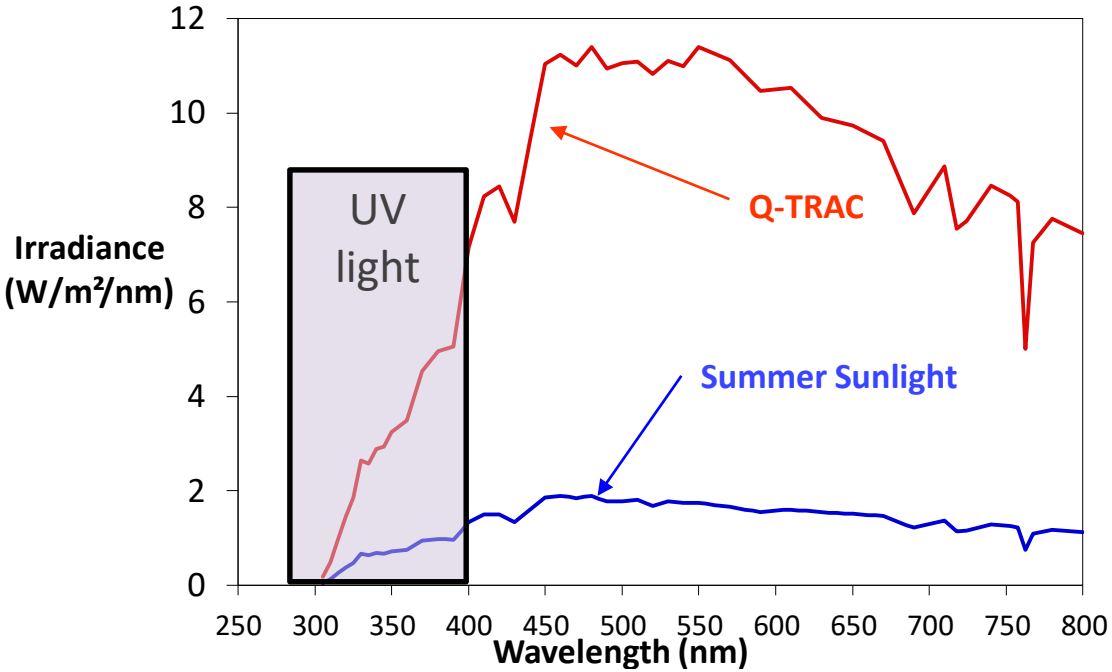
For organic coatings of fiber reinforced plastics only (AAMA 623, 624, 625)



Following the Sun…



Natural Solar Concentrator Exposure ASTM G90



Equating G90 Light Dosage to Florida

Q-TRAC Energy Equivalent:

One Year in Florida

Exposure Angle	Energy (MJ/m² TUV)
0˚ South	322
5˚ South	339
26˚ South	345
45˚ South	321
90˚ South	170

Q-TRAC delivers ~**1400** MJ/m² annually -
~**5 ×** a typical year in Florida*

Options in Exposure for Coatings on Fiber Reinforced Thermoset Profiles

In exposure of the specimens, ASTM G90 Cycle 3 is used, which includes significant amount of nighttime spray events, increasing specimen water absorption and time of wetness, similar to nighttime wetting due to dew in Florida.

AAMA Standard	Name	Florida Exposure	ASTM G90
AAMA 623	Performance Requirements and Test Procedures for Organic Coatings on Fiber Reinforced Thermoset Profiles	1 year	290 MJ (≈3 months)
AAMA 624	Performance Requirements and Test Procedures for **High Performance** Organic Coatings on Fiber Reinforced Thermoset Profiles	5 years	1450 MJ (≈1 years)
AAMA 625	Performance Requirements and Test Procedures for **Superior Performance** Organic Coatings on Fiber Reinforced Thermoset Profiles	10 years	2900 MJ (≈2 years)

How is color measured?

What is Color?

- Color is human's perception of light reflected from an object's surface
- Three criteria to observe color
  - Light Source
    - Natural (Sunlight)
    - Artificial (Incandescent, LEDs, etc.)
  - Object
  - Observer
    - Human
    - Instrumental

Measuring Color

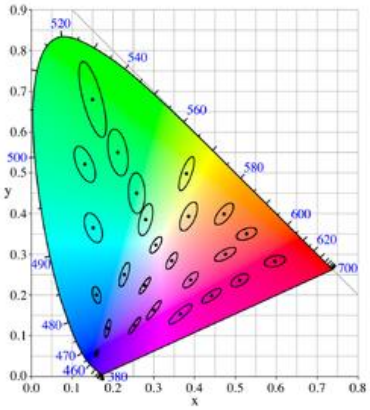
- Colorimetry is the science of quantifying and measuring color
- Color models and spaces have been developed through extensive experiments & understanding of physics, light, & the eye
  - Hunter Lab, CIE Lab, Luv, LCH, XYZ, RGB

Color Difference

- Using color models, along with instrumentation, a color difference between any two objects can be calculated.
- The same object will appear different under different light sources
  - Illuminant C, D, F
  - D65 is considered daylight (6500K color temp)
- Observational variables exist as well
  - 2° Observer versus 10° Observer
  - Specular Component Included (SCI) or Excluded (SCE)

Color Difference

There exist many different methods for evaluating the color difference between two objects, or from a singular object that may change over time due to weathering.



- ΔE_H
- ΔE^*_{ab}
- ΔE2000
- ΔE (CMC)
- ΔL, Δa, Δb, ΔC, ΔH
- Or a customized ellipsoid tolerance

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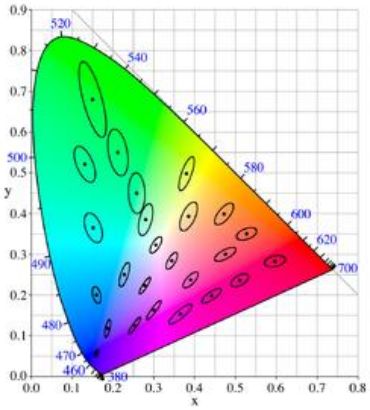

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- ΔE (CMC)
- ΔL, Δa, Δb, ΔC, ΔH
- Or a customized ellipsoid tolerance

AAMA Color Task Group and Color Study

AAMA Study

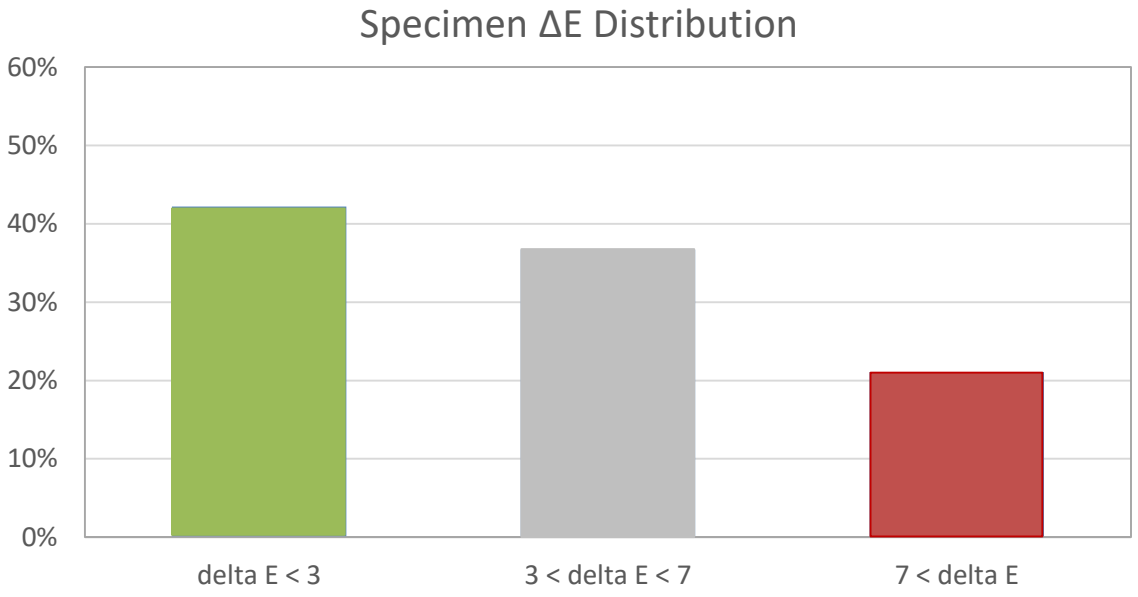
- AAMA standards and performance specifications were originally written for Hunter Lab.
- Through years, standards were revised without clear requirements for evaluation – which color space, which illuminant, which ΔE should be reported.
- Suppliers were reporting multiple ΔE calculations, under different illuminants and using alternative color spaces.
- A task group was formed to review the ΔE_H system, and to evaluate if it is still relevant or should be replaced, with the goal to find the best agreement with the human evaluators and gain consensus on conditions of evaluations.

AAMA Study

- 109 samples of various color and performance were exposed to weathering
- Samples were evaluated instrumentally with spectrophotometer.

Instrument	X-Rite Color I7 (d/8° sphere)			
Color Space	CIE 1976 L*a*b*		Hunter L a b	
Illuminant	D65		C	
Observer	10°		2°	
Specular Component	Included	Excluded	Included	Excluded
Color Difference Equation	ΔE^*, ΔE_{2000}	ΔE^*, ΔE_{2000}	ΔE_H	ΔE_H

Instrument Evaluation



Distribution of resulting ΔE values from weathered specimens
(Hunter, Illuminant C, 2 degree observer, specular component excluded)

Instrument Evaluation

System	Specular Component	Average	Pass (< 5)	Fail (> 5)
Hunter ΔE_H	Included	3.19	73%	27%
CIE ΔE*	Included	4.06	66%	34%
CIE ΔE2000	Included	2.21	91%	9%
Hunter ΔE_H	Excluded	4.36	64%	36%
CIE ΔE*	Excluded	5.96	55%	45%
CIE ΔE2000	Excluded	3.14	82%	18%

- It is *'Easier'* to pass the ΔE2000 system.
  - That is, a sample that may have failed the Hunter ΔE, could have passed ΔE2000 due to tolerancing.

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Consumer Perception			???	???

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How does this relate to perception?

How do we relate this to how we judge color change?

Consumer Perception

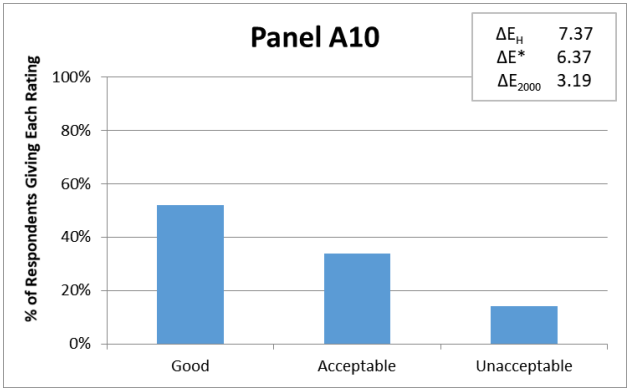
- The 109 weathered specimens were evaluated by a mix of industry professionals and non-technical attendees (98 total).
- Evaluators were told to rate them from the perspective of a consumer who would want to replace components with unacceptable color change.
- Evaluate each specimen with a rating of *Good, Acceptable,* or *Unacceptable*.

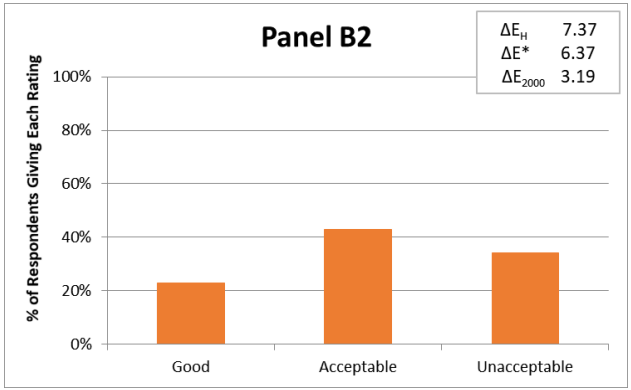
Good (0)

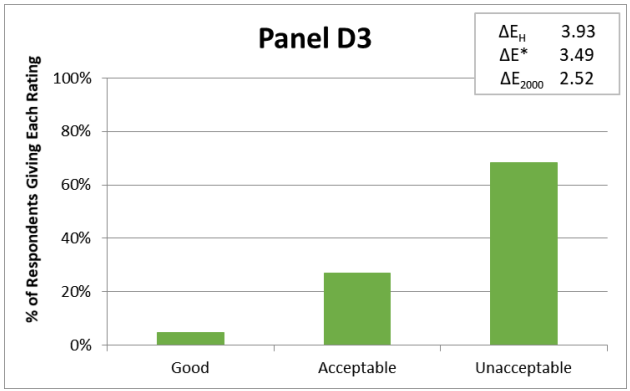
Acceptable (1)

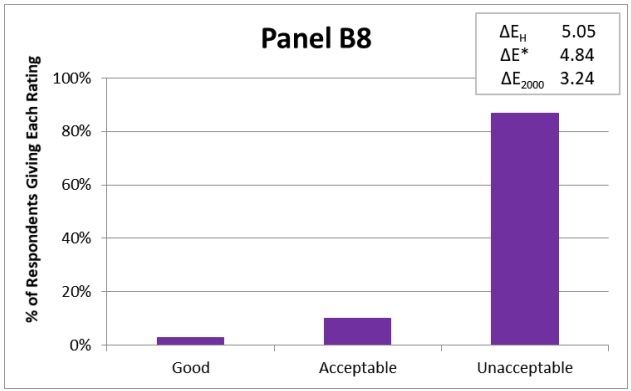
Unacceptable (2)

Evaluator Data









Results of the Consumer Survey

System	Specular Component	Average	Pass (< 5)	Fail (> 5)
Hunter ΔE_H	Included	3.19	73%	27%
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CIE ΔE2000	Excluded	3.14	82%	18%
Consumer Perception		0.99	78%	22%

Note: The remainder of the review will focus on the Specular Component Included (SCI) values.

Correlating Instrument and Perception

		Average Observed Rating	
		Acceptable	Unacceptable
Hunter ΔE_H (SCI)	Pass	67 %	6 %
	Fail	12 %	15 %
CIE ΔE* (SCI)	Pass	61 %	6 %
	Fail	18 %	16 %
CIE ΔE2000 (SCI)	Pass	76 %	14 %
	Fail	2 %	8 %

Potential for Erroneous Results

What the task group was most concerned with is the false positives and false negatives

- **False Negative**
  - specimens that failed the colorimetric criterion but were acceptable in the visual rating
- **False Positive**
  - specimens passed the colorimetric criterion but were actually unacceptable in the visual rating

Instrument and Perception Agreement

		Average Observed Rating	
		Acceptable	Unacceptable
Hunter ΔE_H (SCI)	Pass	**67 %**	6 %
	Fail	12 %	**15 %**
CIE ΔE* (SCI)	Pass	**61 %**	6 %
	Fail	18 %	**16 %**
CIE ΔE2000 (SCI)	Pass	**76 %**	14 %
	Fail	2 %	**8 %**

False Negative

Fail Instrument Reading – Acceptable to Consumers

		Average Observed Rating	
		Acceptable	Unacceptable
Hunter ΔE_H (SCI)	Pass	67 %	6 %
	Fail	**12 %**	15 %
CIE ΔE* (SCI)	Pass	61 %	6 %
	Fail	**18 %**	16 %
CIE ΔE2000 (SCI)	Pass	76 %	14 %
	Fail	**2 %**	8 %

False Positive

Pass Instrument Reading – Unacceptable to Consumers

		Average Observed Rating	
		Acceptable	Unacceptable
Hunter ΔE_H (SCI)	Pass	67 %	**6 %**
	Fail	12 %	15 %
CIE ΔE* (SCI)	Pass	61 %	**6 %**
	Fail	18 %	16 %
CIE ΔE2000 (SCI)	Pass	76 %	**14 %**
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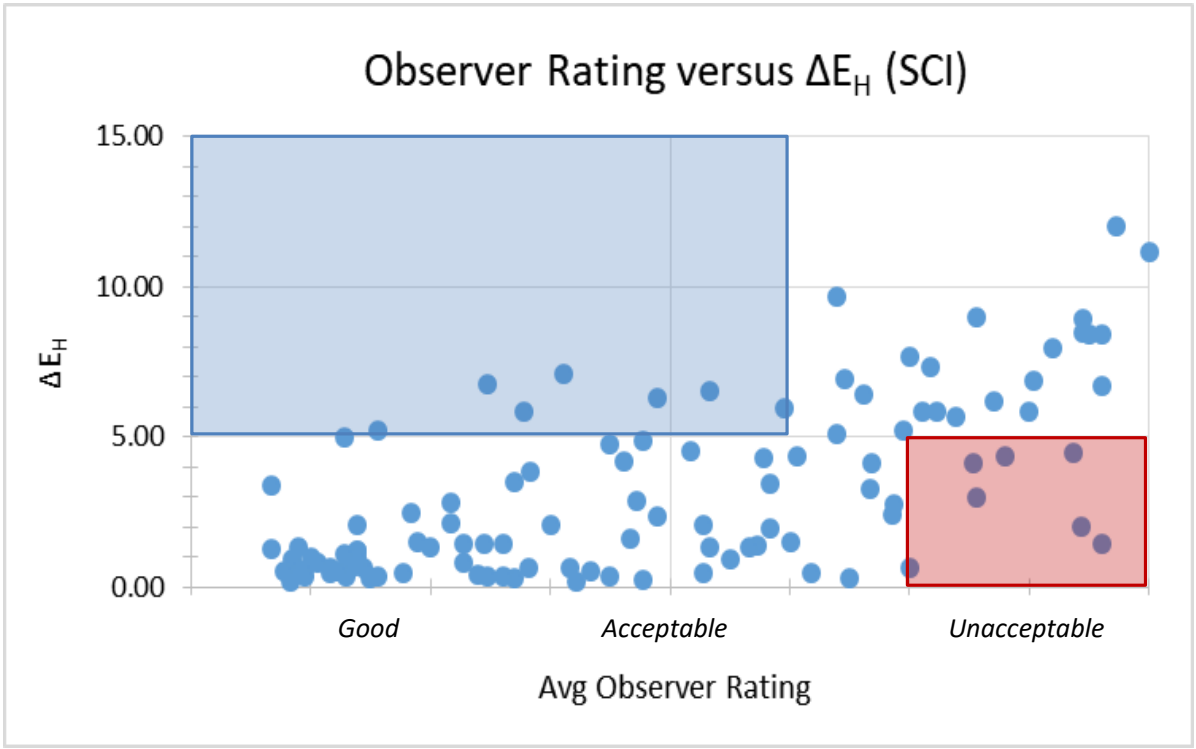
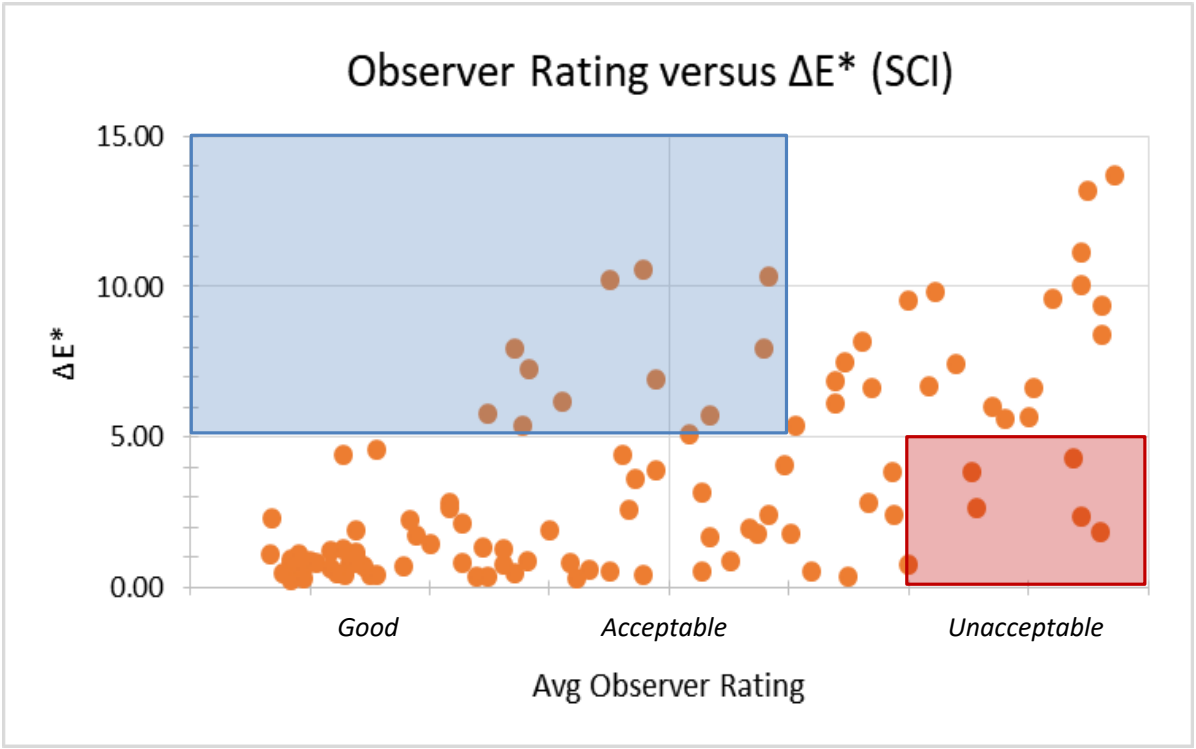
Visual versus ΔE_H (SCI)



*Highlighted **Blue** – False Negatives*
*Highlighted **Red** – False Positives*

Visual versus ΔE* (SCI)



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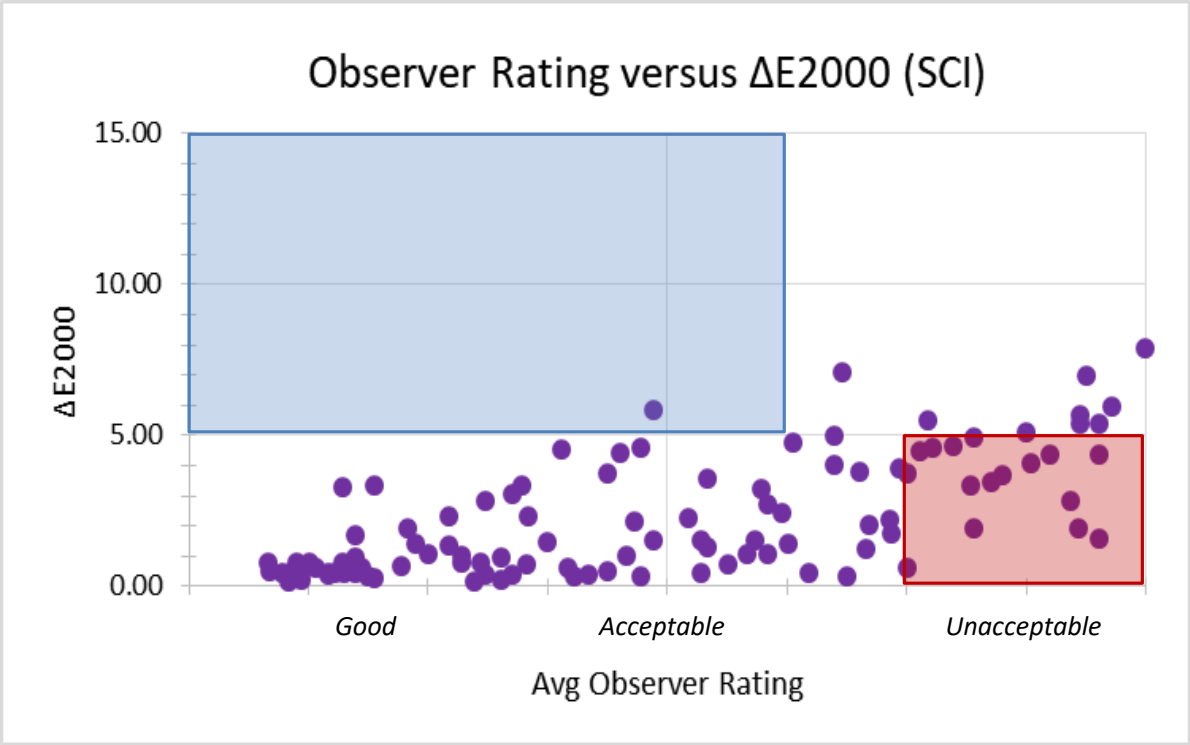
Visual versus ΔE2000 (SCI)



*Highlighted **Blue** – False Negatives*
*Highlighted **Red** – False Positives*

Adjusting Performance Criterion

Visual False Negatives and Positives			
Instrumental Measurement	Agreement	False Negatives	False Positives
$\Delta E_H \geq 5$	82%	12%	6%
$\Delta E_H \geq 6$	83%	7%	10%
$\Delta E^*_{ab} \geq 5$	76%	18%	6%
$\Delta E^*_{ab} \geq 6$	79%	14%	7%
$\Delta E_{2000} \geq 5$	84%	2%	14%
$\Delta E_{2000} \geq 4$	85%	7%	7%

AAMA Task Group Conclusion

- Using the ΔE2000 color difference equation, and adjusting the fail criteria to ΔE2000 ≥ 4, showed the best agreement of visual and instrumental assessment. Unfortunately, it had a slight increase of false positives.
- Simply switching CIE Lab and maintaining the same fail criteria of $\Delta E^*_{ab} \geq 5$, showed the worst agreement between visual and instrumental assessments.
- The AAMA Color Space Task Group concluded, there was no compelling reason to change from the Hunter color system, where legacy coating formulations with a long exposure history are concerned.
- Standardized on Hunter Lab, D65 Sphere, 10° Observer, Specular Comportment Included.

Conclusions

- As products are exposed to weather, the coatings may fade and change color.
- We can measure color with instruments, plot color change, & set performance criteria, but…
  - How does it compare to human perception and observations?
  - What is the allowable tolerance for consumer acceptance?

  Each application and company must determine their own level of risk.

Questions?

info@q-lab.com