

Evaluation of Advanced Coating Systems for Transmission Line Structures

Status Update for Ovante
January 2019

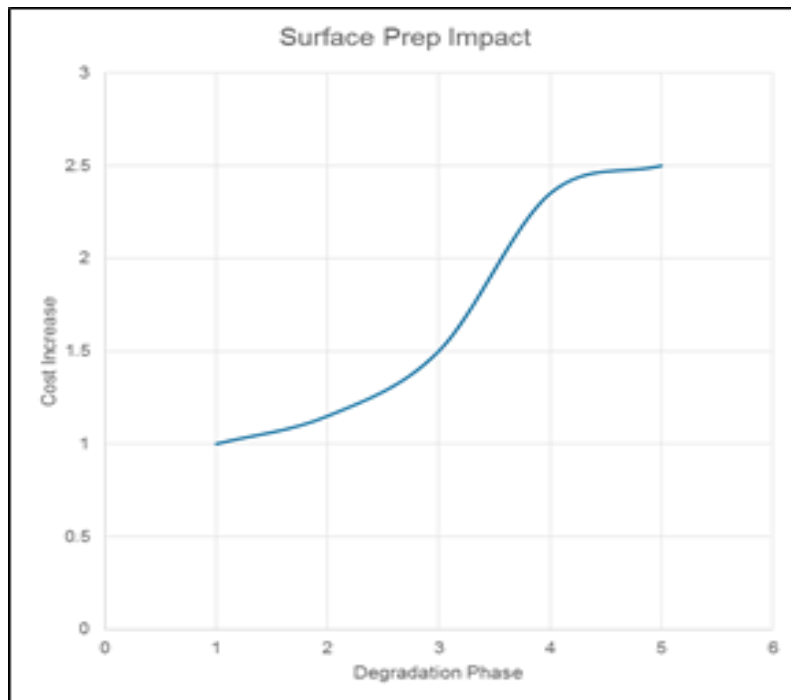
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Background

- Existing coating systems typically provide only a 15 – 20 year service life.
- Reapplication of coating systems are costly and have a limited service life.



Scope

Objectives

- To identify and evaluate coating systems that may provide a **50-year** service life.
- To test the performance of coating systems under specific corrosive stresses.
- To identify failure-causing factors in the coating technology.
- To provide utilities with impartial information about coating systems.

Approach

- Evaluate adherence to coating application specifications;
- Evaluate changes to physical characteristics after accelerated environmental exposure;
- Evaluate coating performance under mechanical and electrical stresses.

Laboratory Evaluation

Evaluate coating systems in a laboratory environment by quantifying specific attributes and establishing minimum performance thresholds for extended service life.

Accelerated Aging

- 1200 hours – hot water immersion
[ASTM D870-02]
- 1200 hours – salt fog
[ASTM B117-03]
- 1200 hours – UV exposure
[ASTM G154-06]

Testing

Attribute	Test Name	Governing Standard
Thickness, Filler Material, Test Sample Flaws	Metallography	ASTM E3-01
Electron Endosmosis, Adherence	Adhesion	ASTM D 4541-02
Cathodic Disbondment	Cathodic Disbondment	ASTM G8 (modified)
Resistance to Soil Stress	Impact	ASTM D 2794
	Bend	ASTM D 790
	Chipping Resistance	ASTM D3170/D3170M-14
Undercutting	Scribe/Creep	ASTM D1654-92
Inhibition, Adherence, Moisture Vapor Transfer, Ionic Passage, Biological Damage	EIS	ASTM G106-89
Appearance	Color	ASTM D 2244-05
	Gloss	ASTM D 523 (modified)



Accelerated Aging



Hot water immersion



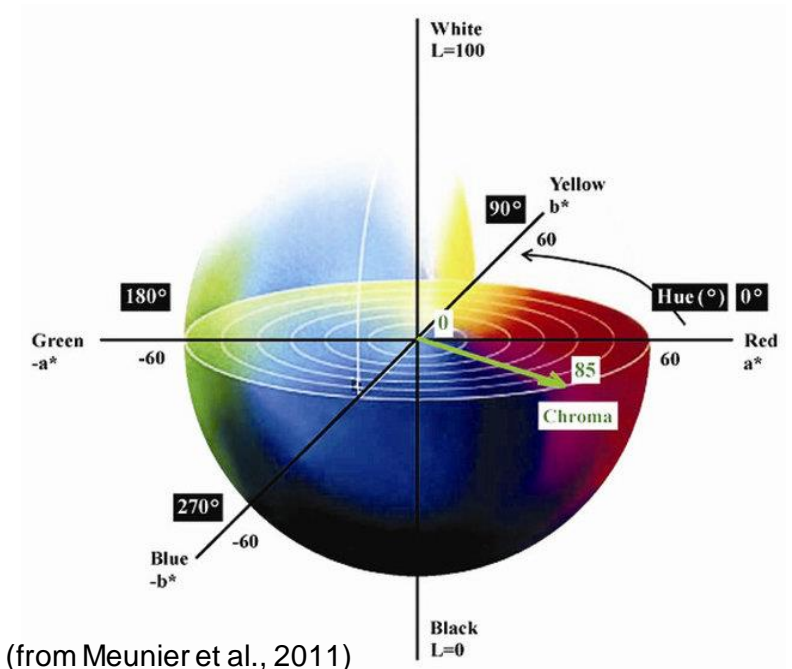
Cyclic salt spray chamber

Storm Greeter™ Results

Color Retention Test

To determine how the coating appearance changes when exposed to different aging protocols.

Rating	Performance Criteria
Excellent	$\Delta E \leq 5$
Good	$5 < \Delta E \leq 10$
Fair	$10 < \Delta E \leq 20$
Poor	$\Delta E > 20$



CIELab color space diagram (from Meunier et al., 2011)

Aging Protocol	Avg L*	Avg a*	Avg b*	ΔE	Performance
Baseline	90.6	4.23	26.9	N/A	N/A
UV	71.8	3.41	21.9	19.4	Fair
Salt Spray	90.4	4.26	27.1	0.312	Excellent
Immersion	100.1	3.80	27.4	9.57	Good

Lightness (+)
Darkness (-)

Red (+)
Green(-)

Yellow (+)
Blue (-)

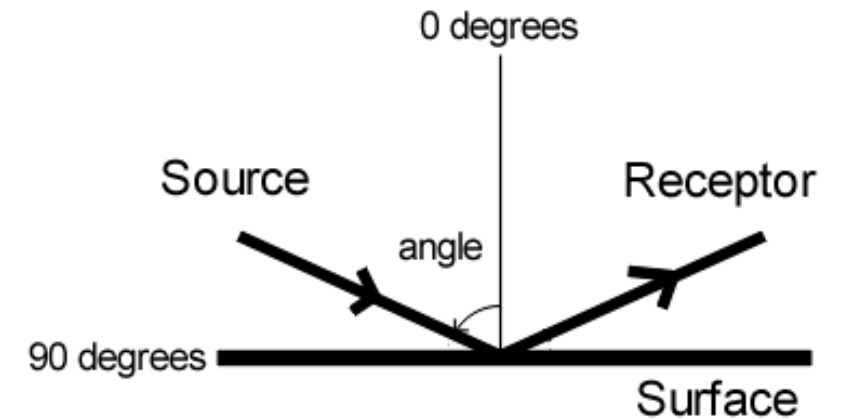
Total Color Difference

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

Gloss Retention Test

To determine how the coating luster changes when exposed to different aging protocols.

Rating	Performance Criteria
Excellent	$\leq 5\% \Delta\text{GU}$
Good	6 – 19% ΔGU
Fair	20 – 34% ΔGU
Poor	$\geq 35\% \Delta\text{GU}$



Gloss Measurement

Image from <http://www.paintinfo.com/mpi/approved/sheen.shtml>.

0 Gloss Units (GU): completely matte surface → 100 Gloss Units (GU): polished black glass

Aging Protocol	Avg GU	$\Delta\text{GU}\%$	Performance
Baseline	38.9	N/A	N/A
UV	17.9	54.0	Poor
Salt Spray	45.7	17.6	Good
Immersion	52.0	33.6	Fair

Overall Appearance Retention

Baseline

UV

Salt

Immersion



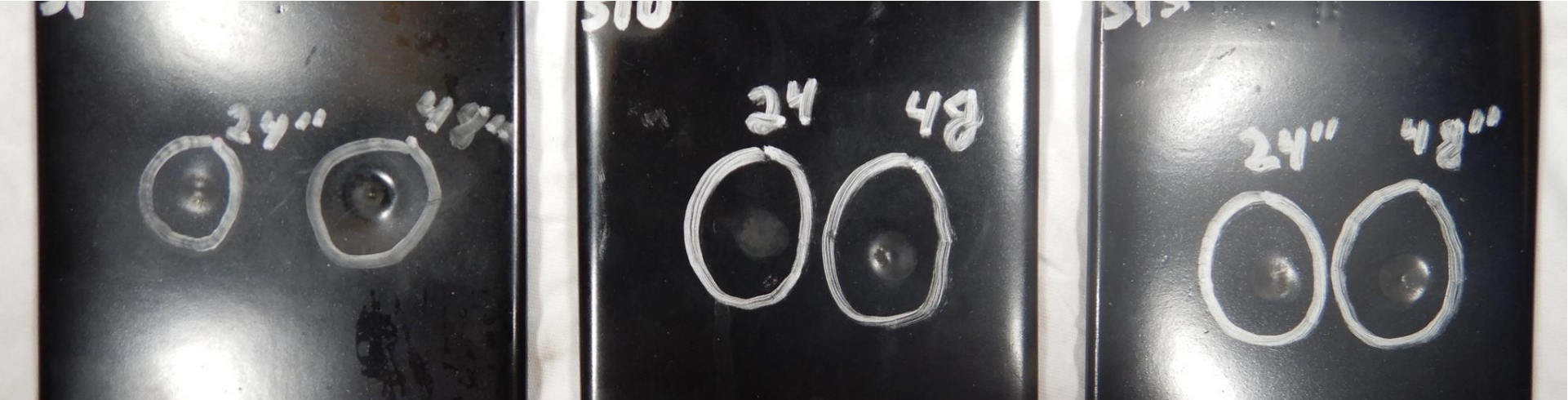
Impact Test

Shows the durability of the coating during rapid deformation.

Rating	Performance Criteria
Excellent	No cracking or exposed sub-layers
Good	Minor cracking in coating but no substrate exposed
Fair	Minor cracking & substrate visible OR Major cracking but no substrate exposed
Poor	Major cracking or loss of coating and substrate visible

Aging Protocol	Drop Height (in)	Degree of Cracking	Substrate Exposed?	Rating
Baseline	24	None	No	Excellent
	48	None	No	Excellent
UV	24	None	No	Excellent
	48	None	No	Excellent
Salt Spray	24	None	No	Excellent
	48	None	No	Excellent
Immersion	24	None	No	Excellent
	48	None	No	Excellent

Impact Test



Baseline

Salt

Immersion

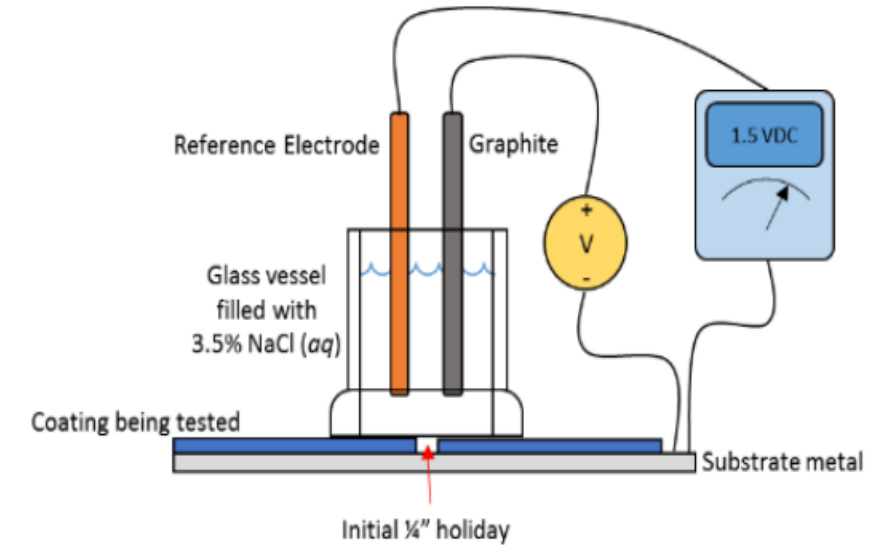


UV

Cathodic Disbondment

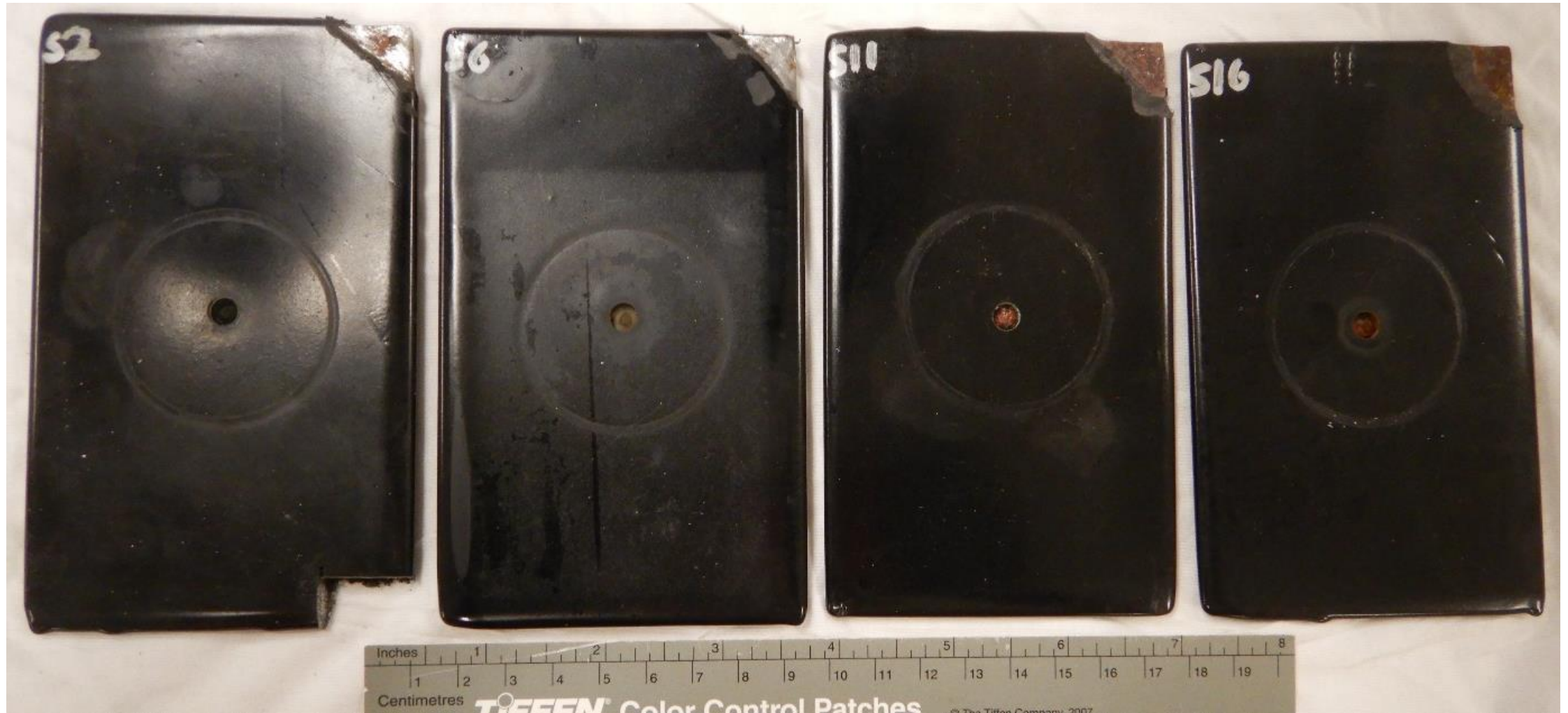
Measures how the coating bonding can handle electrical stresses.

Rating	Performance Criteria (non-conductive)
Excellent	No disbonded coating evident
Good	25% or less of exposed area disbonded between layers (not to substrate)
Fair	Greater than 25% of exposed area disbonded between layers (not to substrate)
Poor	Any disbonding to substrate



Aging Protocol	Area Disbonded (%)	To Substrate?	Rating
Baseline	0	No	Excellent
UV	0	No	Excellent
Salt Spray	0	No	Excellent
Immersion	0	No	Excellent

Cathodic Disbondment



Baseline

UV

Salt

Immersion

Chipping Resistance Test via Gravelometer

Evaluates the ability to withstand impact from light, sharp objects.

Number categories for chip ratings

Rating Number	Number of Chips
10	0
9	1
8	2-4
7	5-9
6	10-24
5	25-49
4	50-74
3	75-99
2	100-149
1	150-250
0	>250

Size categories for chip ratings

Rating Letter	Size of Chips
A	<1 mm (approximately 0.03 in.)
B	1-3 mm (approximately 0.03-0.12 in.)
C	3-6 mm (approximately 0.12-0.25 in.)
D	>6 mm (approximately 0.25 in.)

Rating	Performance Criteria
Excellent	No chipping or exposed sub-layers
Good	Minor chipping within the coating layers but no substrate exposure (6 - 10 A – D)
Fair	Major chipping within the coating layers but no substrate exposure (0 – 5 A – D)
Poor	Any chipping to the substrate

Aging Protocol	Quantity	Size	Substrate Exposed?	Rating
Baseline	9	A	No	Good
	6	B		
	6	C		
UV	-	-	No	Excellent
Salt Spray	6	A	No	Good
	6	B		
	6	C		
	6	D		
Immersion	6	A	No	Excellent
	6	B		
	6	C		

Chipping Resistance Test via Gravelometer



Baseline

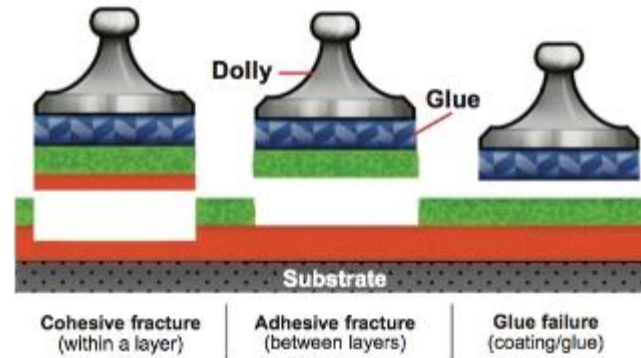
Salt

Immersion

UV

Adhesion Pull-off Test

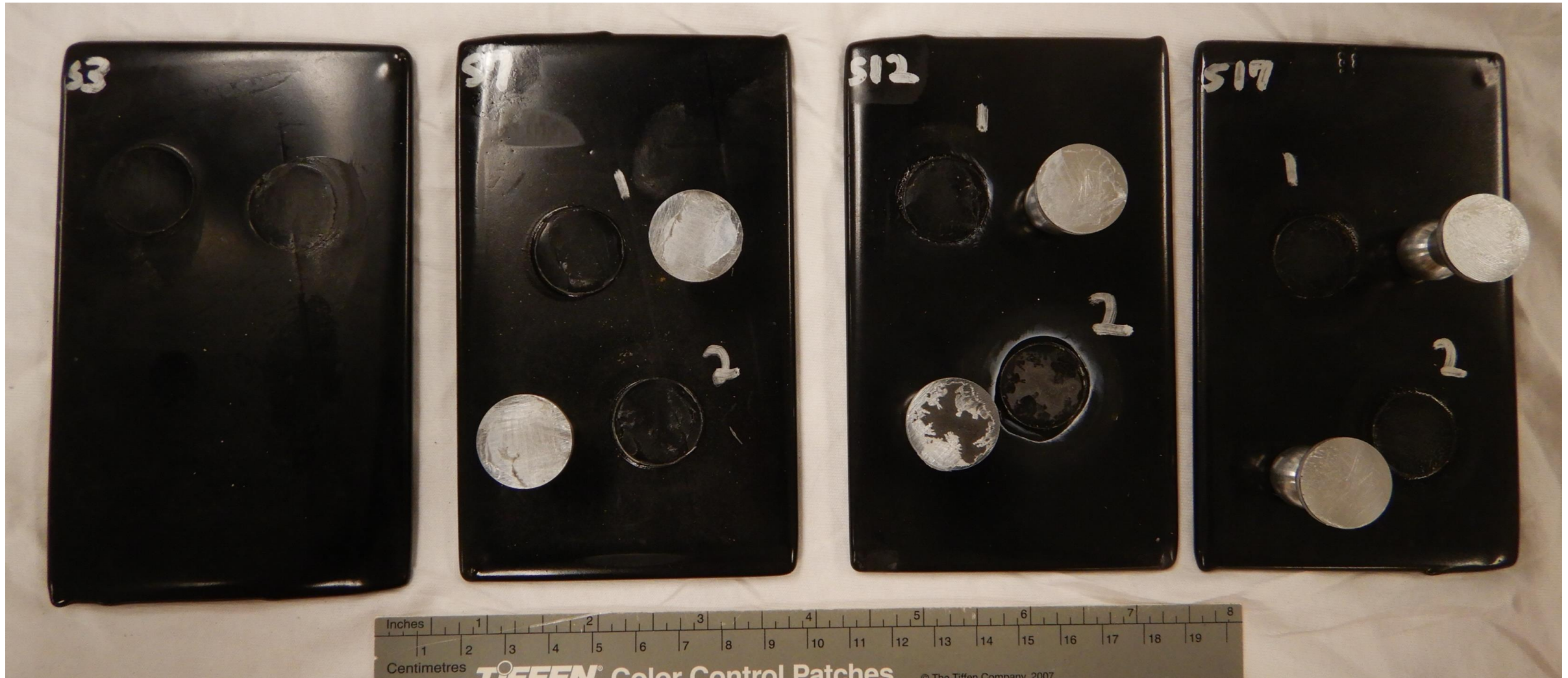
Measures the adhesive and cohesive properties of the coating system.



Rating	Performance Criteria
Excellent	1000+ psi; 100% glue failure or adhesive/cohesive failure w/o substrate exposure
Good	1000+ psi; adhesive failure w/ substrate exposure
Fair	< 1000 psi; adhesive/cohesive failure w/o substrate exposure
Poor	< 1000 psi; adhesive failure w/ substrate exposure

Aging Protocol	Pressure (psi)	% Adhesion Failure	% Cohesion Failure	% Glue Failure	Substrate Exposure?	Overall Rating
Baseline	1515	0	0	100	No	Excellent
	1487	0	0	100	No	
UV	1913	0	0	100	No	Excellent
	2328	0	10	90	No	
Salt Spray	1662	0	0	100	No	Excellent
	2030	0	40	60	No	
Immersion	1882	0	0	100	No	Excellent
	1011	0	0	100	No	

Adhesion Pull-off Test



Baseline

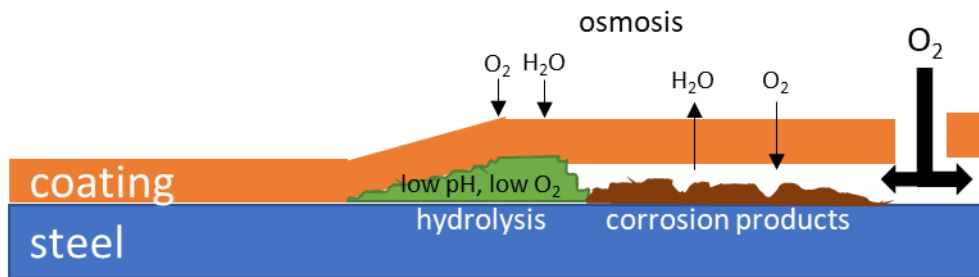
UV

Salt

Immersion

Scribe/Creep Test

Evaluates filiform corrosion during the different aging protocols.



Rating	Performance Criteria
Excellent	No creepage evident.
Good	Average creep distance < 1/16".
Fair	Average creep distance between and including 1/16" and 1/4".
Poor	Average creep distance > 1/4".

Aging Protocol	Creep Distance (in)	Rating
UV	0	Excellent
Salt Spray	< 1/16"	Good
Immersion	0	Excellent

Scribe/Creep Test



UV



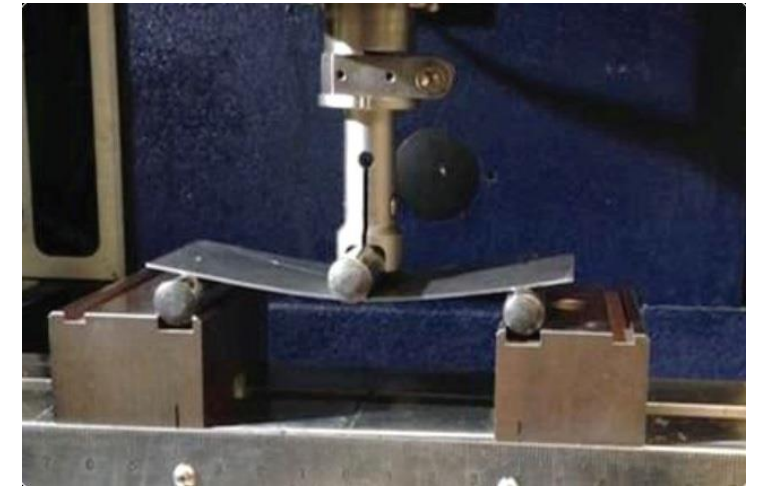
Salt



Immersion

Modified 3-point Bend Test

A qualitative inspection of overall flexural behavior and comparison of flexural properties to baseline performance.



Baseline

UV

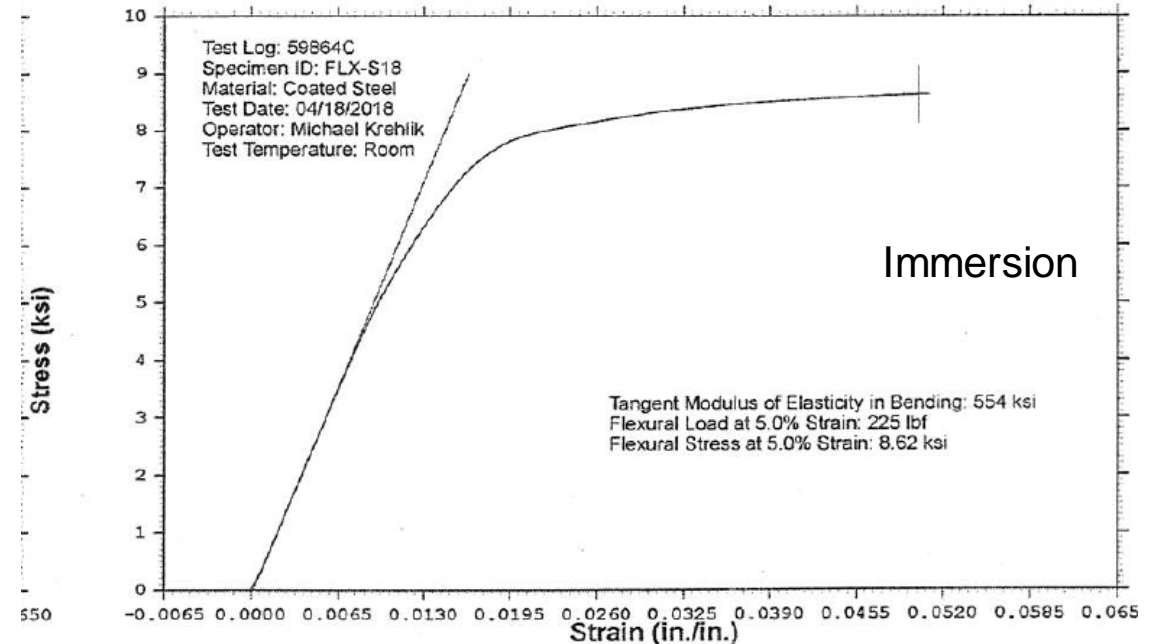
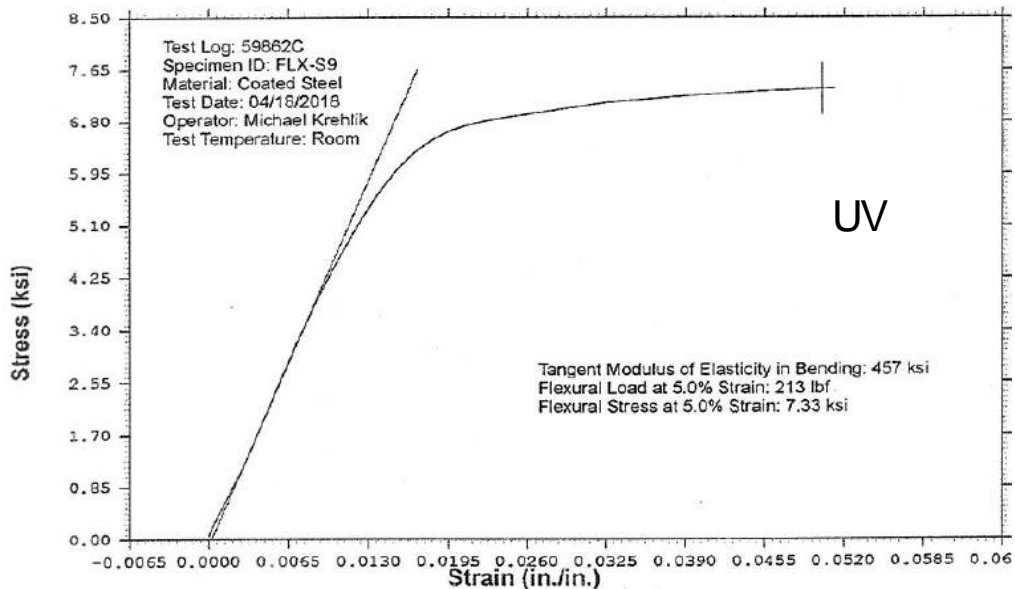
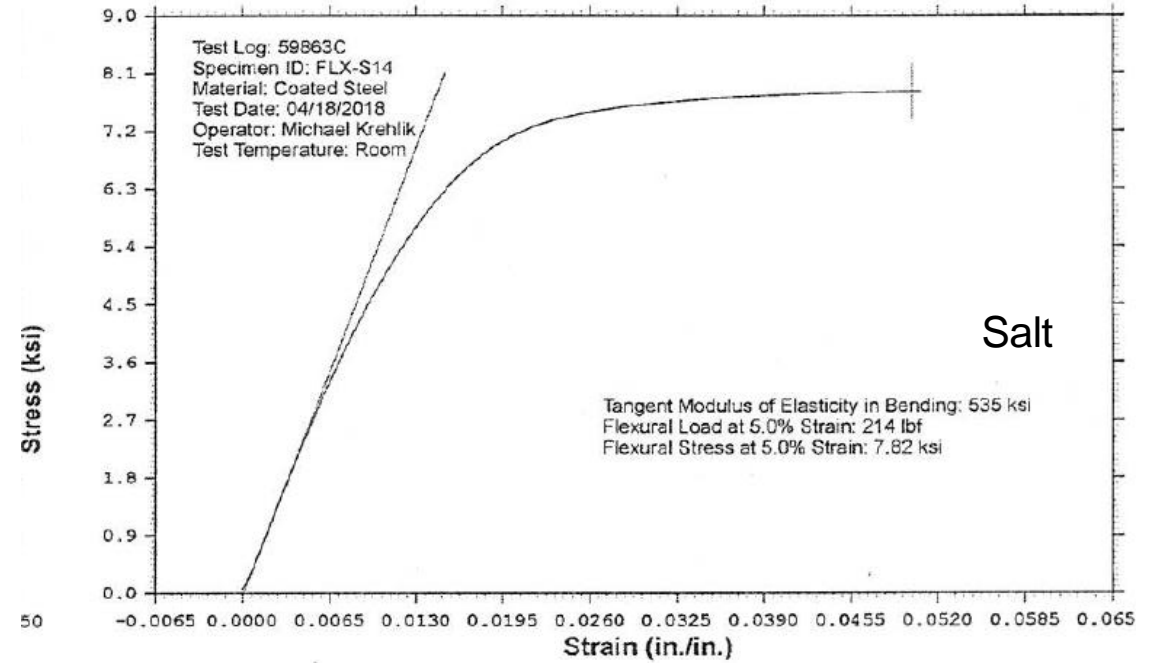
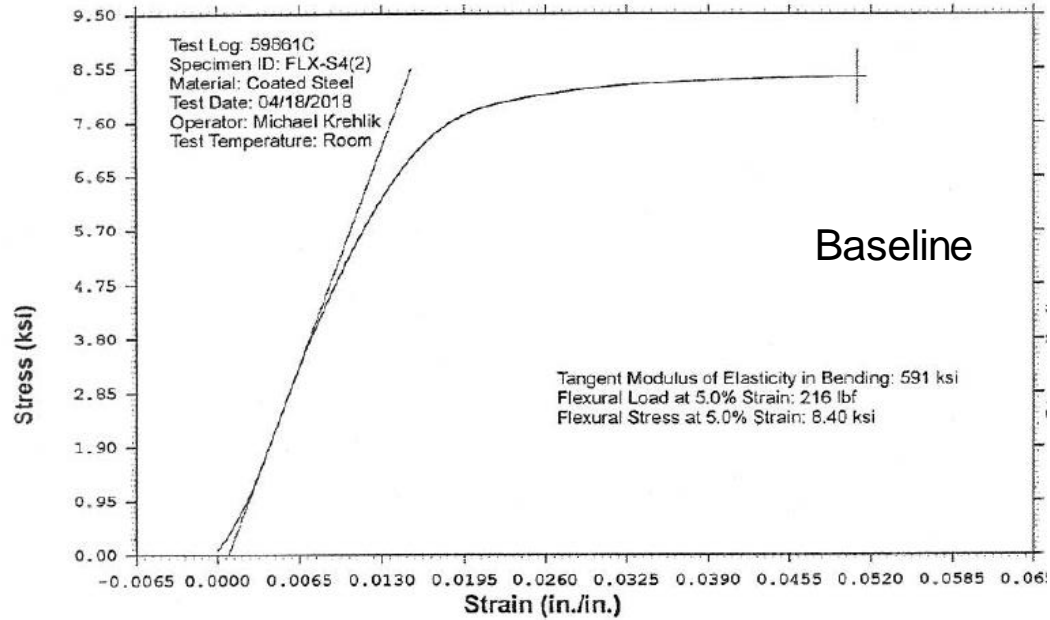
Salt

Immersion



Aging Protocol	Flexural Stress @ 5.0% Strain (ksi)	Flexural Modulus (ksi)	Cracking?
Baseline	8.40	591	None
UV	7.33	457	None
Salt Spray	7.82	535	None
Immersion	8.62	554	None

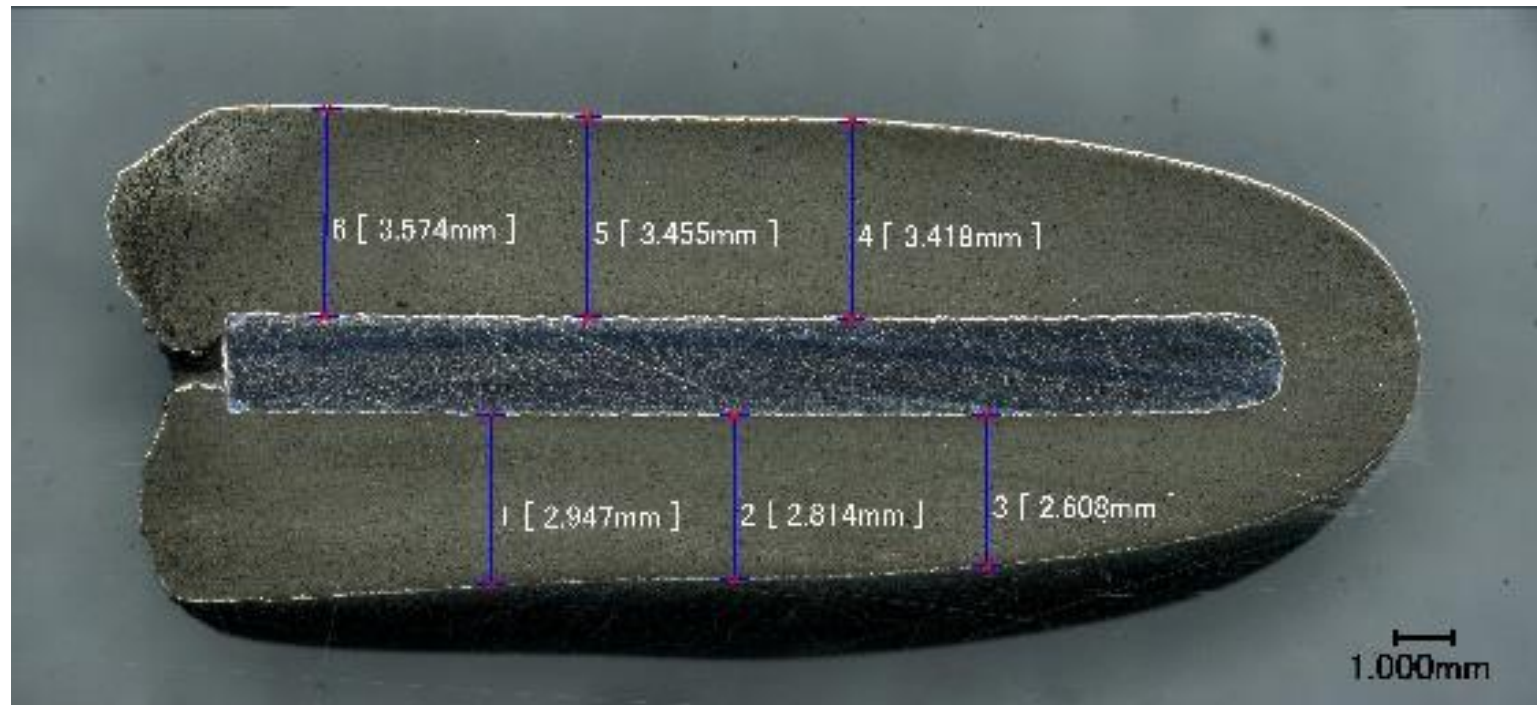
Modified 3-point Bend Test



Metallography

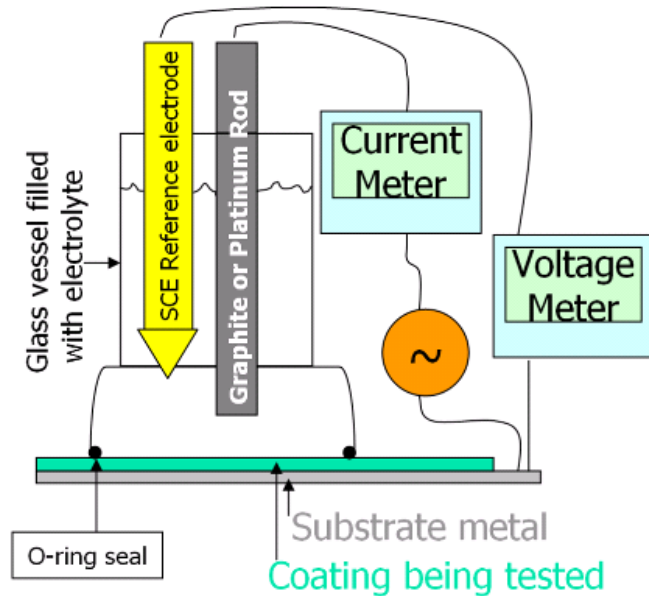
To microscopically evaluate the dry film thickness of all coating layers.

Component	Recommended DFT	Average Observed DFT	Rating
Storm Greeter™	60 – 90 mils	123.5 mils	Exceeds max.



EIS (Electrochemical Impedance Spectroscopy)

The EIS test measures the effects of the aging protocols on resistance and capacitance of the coating – both of which are quantifiable functions of degradation.



Summary Results

Aging Protocol	Gloss	Color	Scribe/Creep	Pull-off	Impact (24")	Impact (48")	Chipping	Cathodic Disbondment
Baseline	X	X	X	E	E	E	G	E
UV	P	F	E	E	E	E	E	E
Salt Spray	G	E	G	E	E	E	G	E
Immersion	F	G	E	E	E	E	E	E

Summary Results

- In a preliminary attempt to rank performance of the coating systems tested in this project, numerical values were assigned to each rating then totaled.
- For this point system, excellent ratings were assigned a 4, good ratings a 3, fair ratings a 2, and poor ratings a 1.

Coating System	Total
2-component spray coating	92
Storm Greeter™	104
2-component powder coating	105
Nanocoating	91
Pure Zn thermal spray coating	86
Zn-Al thermal spray coating	70
2-component polyurea hybrid coating	100

Questions?

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