

Accelerated Performance Evaluation of Railcar Coatings: A State of the Art Update

Brian Skerry

The Sherwin-Williams Company

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Omaha, Nebraska



Testing Paints – Fitness for Use

Standardized Testing Methods – Physical/Performance Properties

- ◆ **ASTM D5894** *Standard Practice for Cyclic Salt-Fog/UV Exposure of Painted Metal (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)*
- ◆ **ASTM B117** *Standard Practice for Operating Salt Spray (Fog) Apparatus*
- ◆ **ASTM D4587** *Standard Practice for Fluorescent UV-Condensation Exposures of Paint and Related Coatings*
- ◆ **ASTM D4585** *Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation*
- ◆ **ASTM D1735** *Standard Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus*
- ◆ **ASTM D4541** *Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers*
- ◆ **ASTM D522** *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*
- ◆ **ASTM D2794** *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation*
- ◆ **ASTM D4060** *Standard Test method for Abrasion Resistance of Organic Coatings with Taber Abraser*
- ◆ **ASTM D870** *Standard Practice for Testing Water Resistance of Coatings Using Water Immersion*
- ◆ **ASTM G8** *Standard Test Methods for Cathodic Disbonding of Pipeline Coatings*
- ◆ **ASTM G95** *Standard Test Method for Cathodic Disbondment Test of Pipeline Coatings (Attached Cell Method)*
- ◆ **NACE TM0174 Method A & B** *Standard Test Method – Laboratory Methods for the Evaluation of Protective Coatings and Lining Materials on Metallic Substrates in Immersion Service*
- ◆ **ISO 20340 (NORSOK)** *Paints and varnishes — Performance requirements for protective paint systems for offshore and related structures*
- ◆ **ISO 12944** *Paints and varnishes – Corrosion protection of steel structures by protective paint systems*

Accelerated Coatings Testing – *Lab*

Standardized Lab Test Equipment

PHYSICAL PROPERTIES

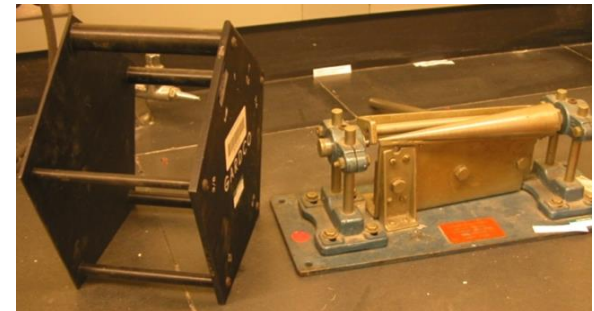
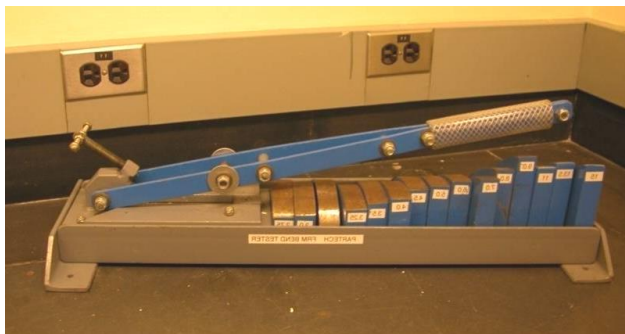
Impactors
Taber abrasion tester (dual),
Conical mandrel tester
Cylindrical mandrel tester
Heavy-duty fixed radial tester
Hydraulic press
Ovens
Gravelometer

PERFORMANCE PROPERTIES

Electrochemical Potentiostats/Multiplexers/Function Analyzers
Atlas cells / Corrocells
Reaction flasks for full immersion testing
Oil baths
Water baths
Salt fog chambers
Q-Fogs
Programmable Cyclical Environmental Chambers
Humidity chambers
QUV cabinets
Cleveland Condensation cabinets
Cathodic Disbondment Tanks
Xenon Arc Weatherometers

Physical Testing - *Lab*

- ◆ Adhesion
- ◆ Flexibility
- ◆ Impact
- ◆ Abrasion



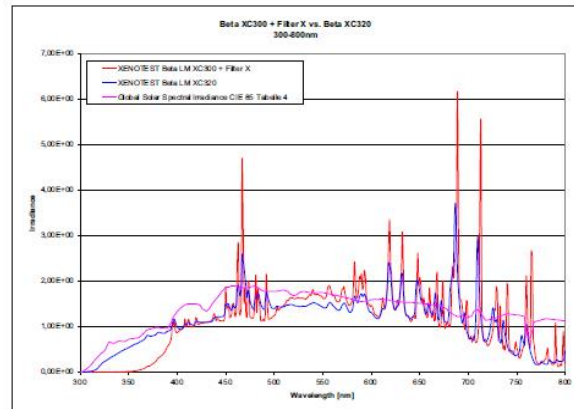
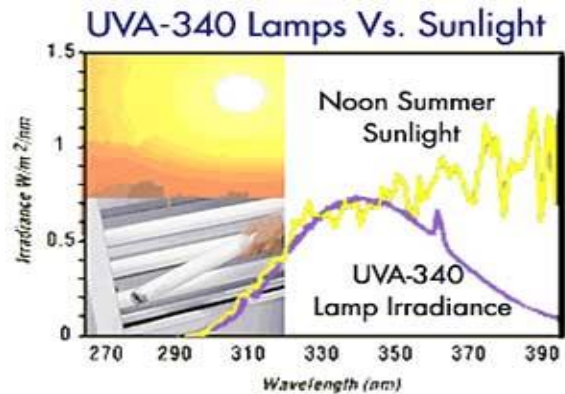
Performance Testing

- Weathering/Durability
 - *Color*
 - *Gloss*
- Corrosion Resistance
 - *Rusting*
 - *Blistering*
 - *Delamination*
 - *Undercutting*



Weathering Tests – Lab

- Q-UV
- Xenon Arc Weatherometer



Weathering Testing - Exterior

- Solar concentrator: Low-Temperature EMMA[®]/EMMAQUA[®]
- Natural Exposures

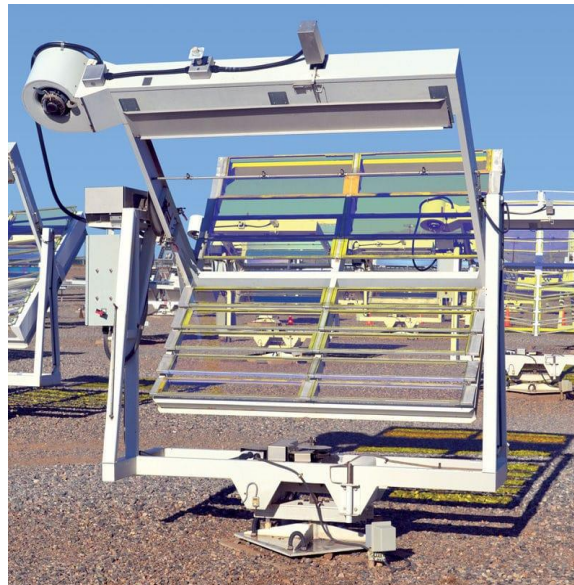
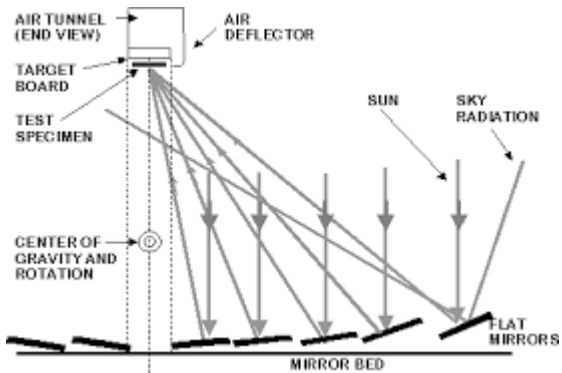
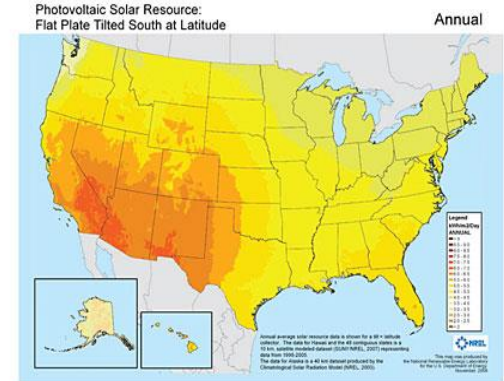
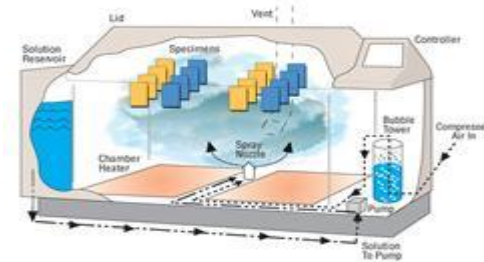


FIGURE 1 | U.S. map of solar radiation - annual dosage; at latitude.¹



Corrosion Testing – *Lab*

- Salt-Fog ASTM B-117
- Wet/Dry Cyclic Testing ASTM G-95
- Cyclic Corrosion/Weathering Testing ASTM D-5894



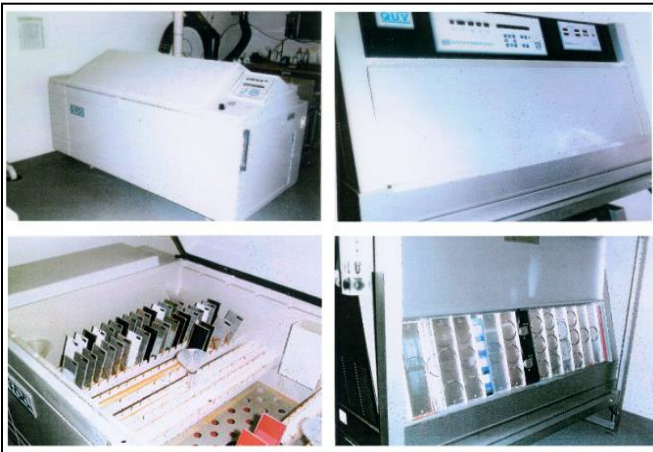
Test Methods – Product Development

Mimic the Service Environment

Accelerate the correct rate determining step

Required Correlation: (Lab vs. 'in service')

- * Rank order performance
- * Degradation (rusting/blistering/delamination)
- * Intact paint (polymer/resin chemistry changes)
- * Damaged sites (structure/morphology/chemistry of corrosion products)



Epoxy Primer/Epoxy Topcoat (total DFT = ~8mils)
[substrate: cold rolled blast steel (1-2 mil profile)]

1 cm

salt-spray test (2000 hrs) wet/dry cycle test (2000 hrs)

corrosion/weathering test (2000 hrs) marine site exposure (27 months)

Designation: D 5894 - 96

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Standard Practice for
Cyclic Salt Fog/UV Exposure of Painted Metal, (Alternating Exposures in a Fog/Dry Cabinet and a UV/Condensation Cabinet)¹

This standard is listed under the fast designation D 5894; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript letter (1) indicates an editorial change since the last revision or approval.

1. Scope

1.1 This practice covers basic principles and operating practice for cyclic corrosion/UV exposure of paints on metal, using alternating periods of exposure in two different cabinets: a cycling salt fog/dry cabinet, and a fluorescent UV/condensation cabinet.

1.2 This practice is limited to the methods of obtaining, measuring, and controlling exposure conditions, and procedures. It does not specify specimen preparation nor evaluation of results.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:
D410 Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces²
D114 Test Method for Evaluating Degree of Blistering of Paints²
D1654 Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments³
D4587 Practice for Conducting Tests on Paint and Related Coatings and Materials Using a Fluorescent UV-Condensation Light-and-Water Exposure Apparatus⁴
G53 Practice for Operating Light-and-Water Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials⁴
G85 Standard Practice for Modified Salt Spray (Fog) Testing⁵

3. Summary of Practice

3.1 The test specimens are exposed to alternating periods of one week in a fluorescent UV/condensation chamber and one week in a cyclic salt fog/dry cabinet. The fluorescent UV/condensation cycle is 4.5 UV at 60°C and 4-h condensation at 50°C, using UVA-340 lamps. The fog/dry chamber runs a cycle of 1-h fog at ambient temperature and 1-h dry-off at 35°C. The fog electrolyte is a relatively dilute solution, with 0.05 % sodium chloride and 0.33 % ammonium sulfate.

4. Significance and Use

4.1 The outdoor corrosion of painted metals is influenced by many factors, including: corrosive atmospheres, rain, condensed dew, UV light, wet/dry cycling, and temperature cycling. These factors frequently have a synergistic effect on one another. This practice is intended to provide a more realistic simulation of the interaction of these factors than is found in traditional tests with continuous exposure to a static set of corrosive conditions.

4.2 Results obtained from this practice can be used to compare the relative durability of materials subjected to the specific test cycle used.

4.3 No single exposure test can be specified as a complete simulation of actual use conditions in outdoor environments. Results obtained from exposures conducted according to this practice can be considered as representative of actual outdoor exposures only when the degree of risk correlation has been established for the specific materials being tested. The relative durability of materials in actual outdoor service can be very different in different locations because of differences in UV radiation, time of wetness, temperature, pollutants, and other factors. Therefore, even if results from a specific artificial test condition are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability for a different environment.

4.4 Even though it is very tempting, it is not recommended to calculate an "acceleration factor" relating a hours of laboratory exposure to y months of exterior exposure. Different materials and different formulations of the same material can have significantly different acceleration factors. The acceleration factor also varies depending on the variability in rate of degradation in the laboratory test and in actual outdoor exposure.

4.5 This practice is best used to compare the relative performance of materials tested at the same time in the same exposure device. Because of possible variability between the

¹This practice is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.27 on accelerated testing.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
UV/condensation — ISO 11507			Salt spray — ISO 9227			Low-temp. exposure at (-20 ± 2) °C

Results obtained depend on the test method – not on the coating!

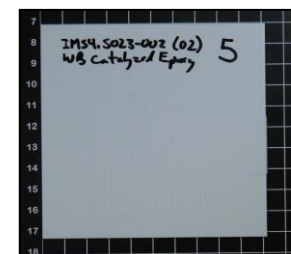
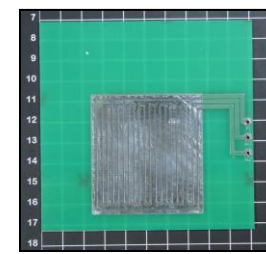
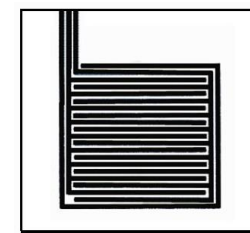
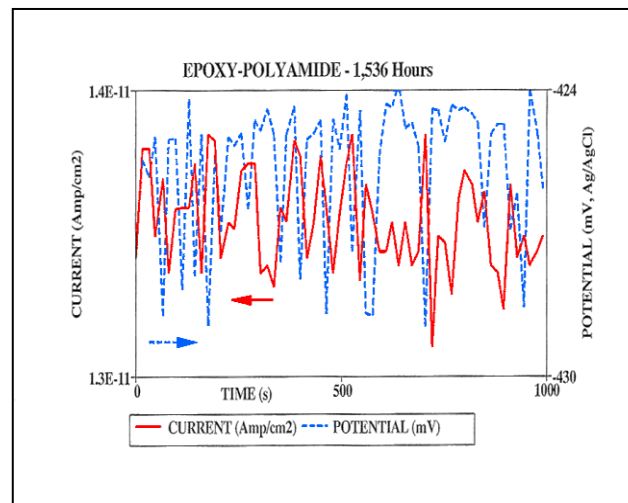
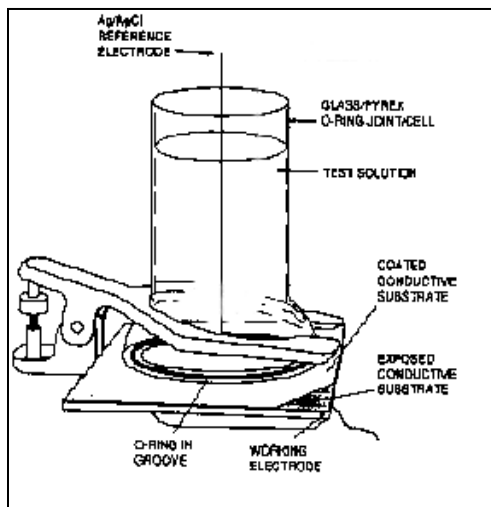
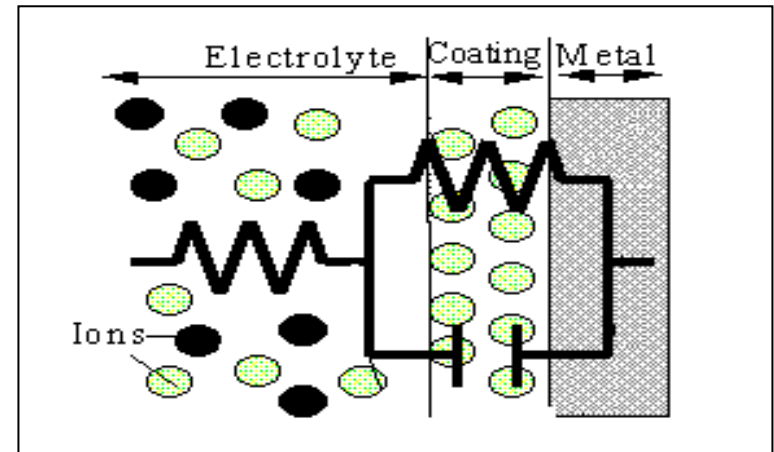
Corrosion – *Electrochemistry*

* Electrochemical Impedance Spectroscopy (EIS)

- Coatings performance ranking.
- Performance changes before visual detection.

* Electrochemical Noise Method (ENM)

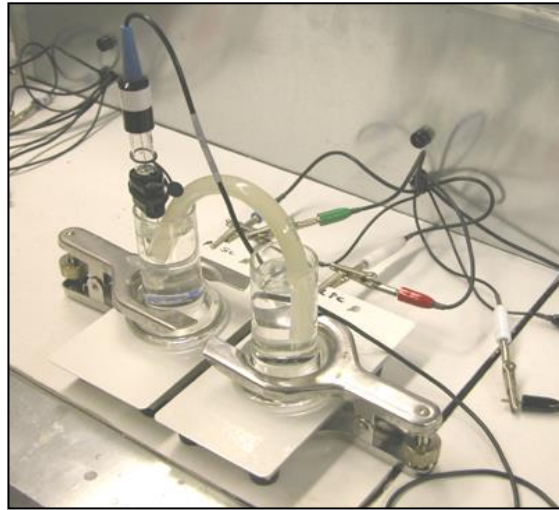
- Coatings performance ranking
- Mechanistic information
- Performance predictions (?)



LABORATORY TESTING – REPRESENTATIVE PROTOCOLS

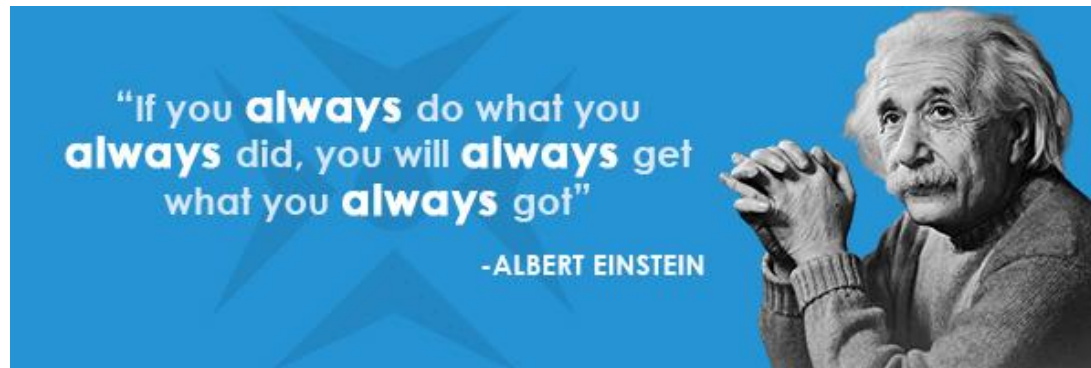
- ISO, NACE, ASTM, MATERIALS SYSTEM SPECIFICATIONS

Atmospheric
Immersion
Chemical resistance
Autoclave
Adhesion
Abrasion resistance
Flexibility
Temperature resistance
Cathodic disbondment
Hardness
Atlas Cell
Application properties
Cure time
Solvent content
DFT
VOC



What's New in Protective Coatings/Testing/Technology?

Roadmap to the Future!



Industry Trends – 2016

Drives Need for Improved Testing Procedures

- Regulations force change (*lower or 0 VOC's/solvent free/0 HAPs*)
- Fewer coats (*2-coats* → *1-coat*)
- Less surface preparation/more surface tolerant
- Faster return to service
- Longer working time/pot life
- Less maintenance
- Single component
- Improved performance/service life



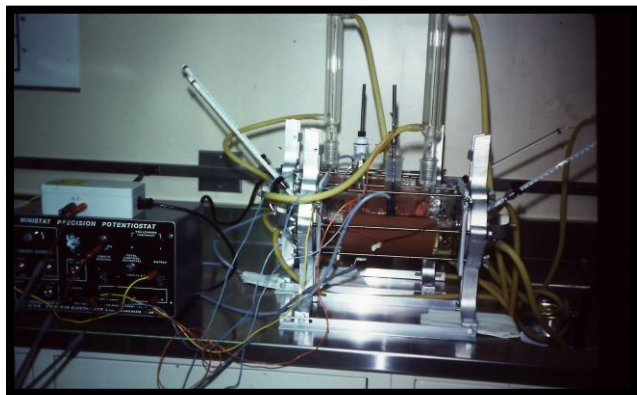
Advancements in Coatings Technology

- High Performance Acrylics - *cross-linking, 0 VOC*
- WB High Build Acrylic Epoxies – *high performance*
- 100% DTM/WB Urethanes – *high performance > S/B (\$\$)*
- Polysiloxanes – *appearance, durability (\$\$)*
- Polyaspartics – *durability, working times, 1-coat (\$\$\$)*
- Fluoropolymers – *appearance, life cycle costs (\$\$\$\$)*
- Styrene-free Vinyl Esters - *safety, HAPS free, 'green'*



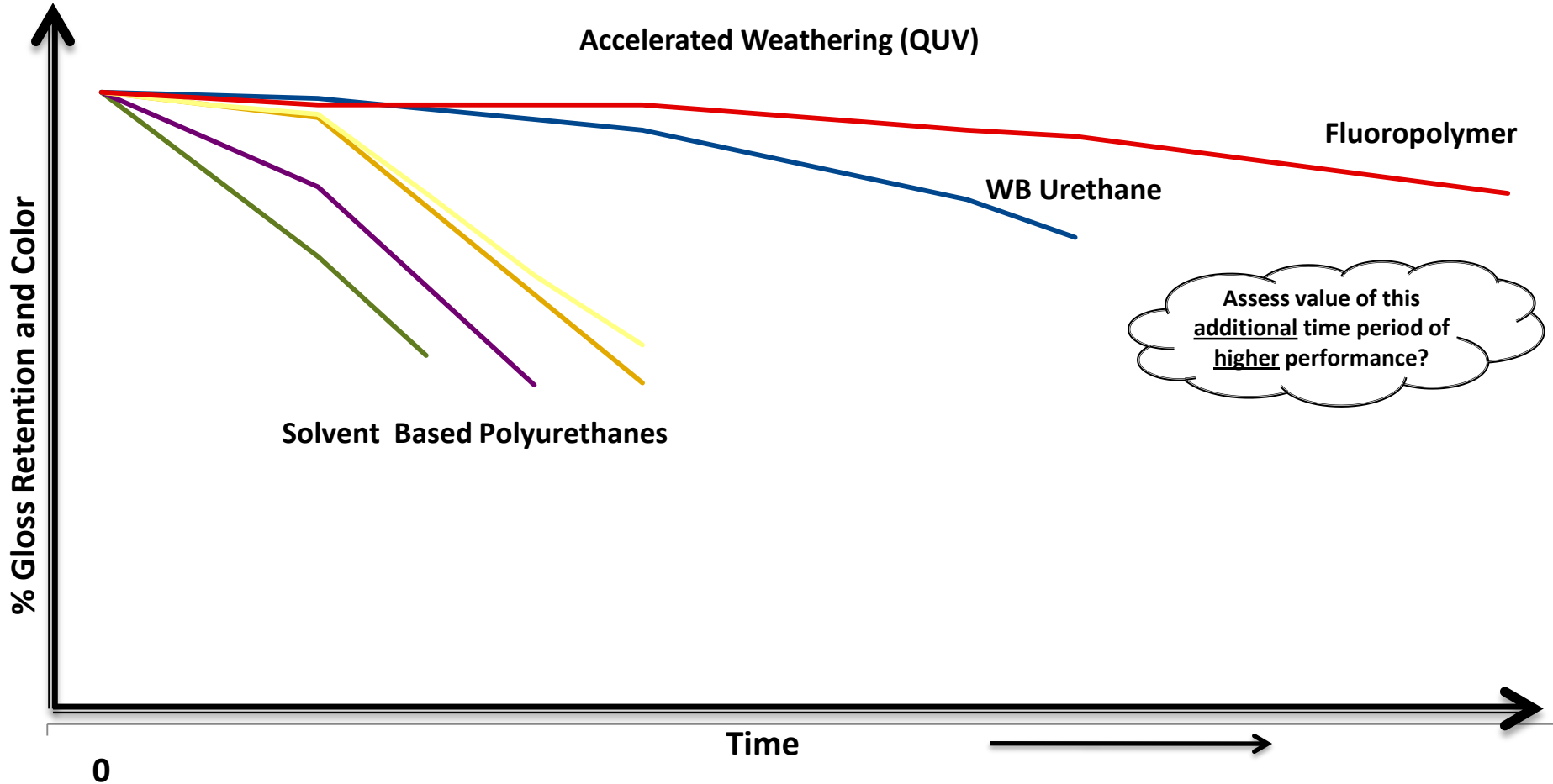
Lab vs. Field - *Correlation*

- **Replicate** *rate determining steps in degradation*
- **Measure/monitor** – *electrochemistry, analytical*

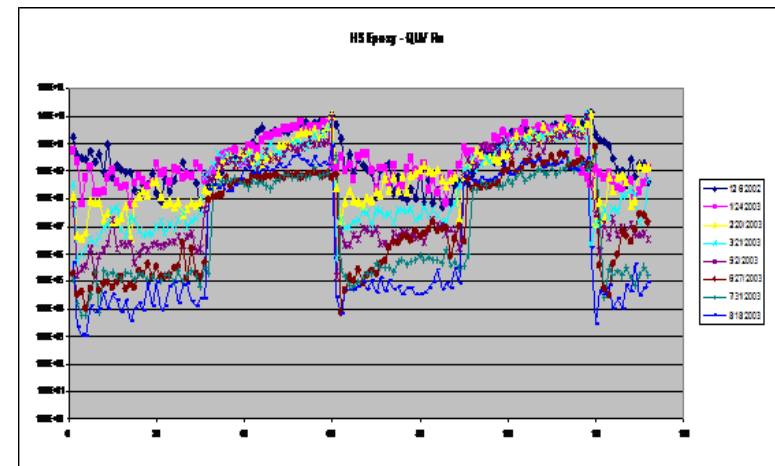
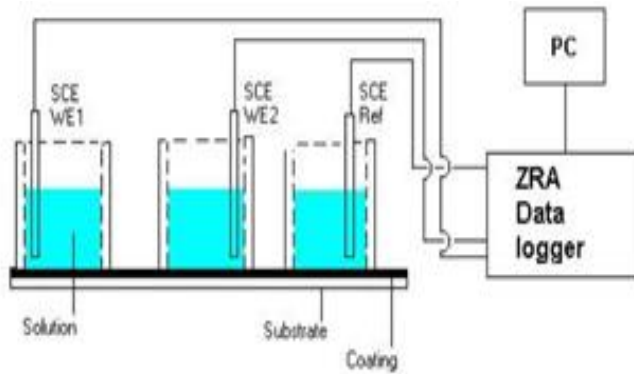
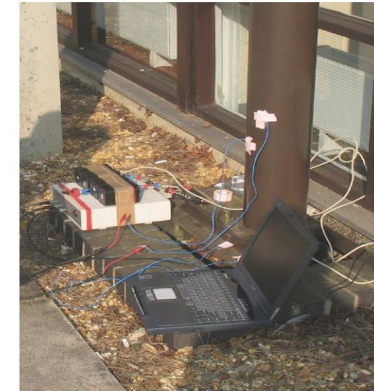
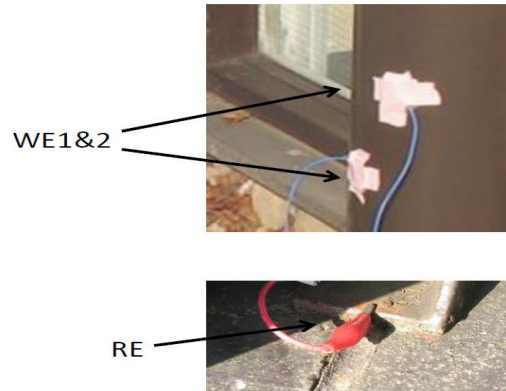
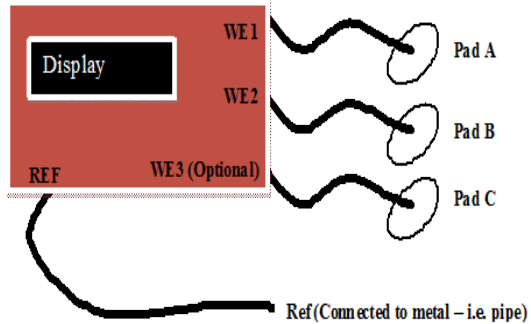


Lab vs. Field - *Correlation*

Accelerated Weathering Testing



Lab vs. Field – Correlation



Where will the future take us?

Improved Test Methods Are Available!

- Water - 1K waterborne = 2K solventborne for steel/atmospheric
- Waterborne tank linings
- New polymer designs
- Nanotechnology
- Engineered surfaces
- Self-healing and smart coatings
- Renewable – resources/biobased

