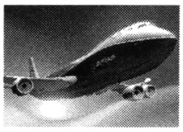
ASTM 7869标准的技术背景，

“针对交通工具用涂料的氙灯老化测试标准的运用”

The Improved Accelerated Weathering Protocol for Transportation Coatings



J. Boisseau

Weathering Team

- BASF (pre 2000)
  - Lynn Pattison
  - Don Campbell
  - Don Barber
- Atlas (2008)
  - Jacob Zhang
  - Matt McGreer
- Bayer (2002)
  - Karen Henderson
  - Don Smith
- Boeing (2010)
  - Jill Seebergh
  - Doug Berry
- Q-Lab (2002)
  - Jeff Quill
  - Greg Fedor
  - Brad Reis
  - Doug Grossman
- Honda (2006)
  - Todd Fitz
  - Nicole Verweys
- Ford (2004)
  - Tony Misovski
  - Cindy Peters
  - Mark Nichols

Protocol Development Timeline

- 2000 – Flaws Determined in existing protocol
- 2002 – Original ideas to develop new protocol
- 2004 – Start of weathering team (others joined from 2006-10)
- 2006 – Beginning of 4 round robin studies
- 2010 – Identification of replacement test protocol
- 2012 – Final validation
- 2013 – ASTM ballot process

SAE J1960/J2527

- For 20+ years, SAE J1960 (now SAE J2527) has been the de facto standard for xenon weathering testing of automotive exterior materials
  - Mid 1980's – Test method development, primarily by GM
  - 1989 – Original publication of SAE J1960, using Quartz/Boro S filters
  - Late 1990's - Adoption of "modified" SAE J1960, using Boro S/Boro S filters
  - 2004 – Development of SAE J2527 – Performance-based version of J1960

Step#	Water Spray	Irradiance (W/m² @340 nm)	Humidity %	Chamber Temperature (°C)	Black Panel Temperature (°C)	Duration (minutes)
1	Off	0.55	50	47	70	40
2	On	0.55	95	47	70	20
3	Off	0.55	50	47	70	60
4	On	0	95	38	38	60

Flaws Identified in J1960/J2527

- Lack of water uptake into deeper coating layers
- Inclusion of light/spray step, not statistically significant
- No relaxation consideration
- Light filters needed improvement
- At one time test was good to predict gloss and color fade, but new technology required an advanced protocol

Balloted ASTM Test Method

Step Number	Step Minutes	Function	Irradiance Set Point[1] @340nm (W/m²/nm)	Black Panel Temperature Set Point[1]	Chamber Air Temperature Set Point[1]	Relative Humidity Set Point[1]
1	240	dark + spray	-	40°C	40°C	95%
2	30	light	0.40	50°C	42°C	50%
3	270	light	0.80	70°C	50°C	50%
4	30	light	0.40	50°C	42°C	50%
5	150	dark + spray	-	40°C	40°C	95%
6	30	dark + spray	-	40°C	40°C	95%
7	20	light	0.40	50°C	42°C	50%
8	120	light	0.80	70°C	50°C	50%
9	10	dark	-	40°C	40°C	50%
10	Repeat steps 6-9 an additional 3 times (for a total of 24 hours = 1 cycle)					

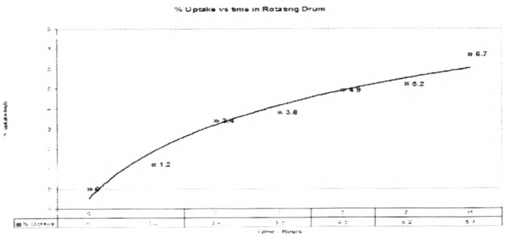
- Longer dark/spray cycles to achieve moisture uptake levels (saturation)
- Multiple irradiance levels to simulate outdoor conditions; High level increases acceleration
- No light/spray together…it doesn't typically rain in max sunshine conditions
- Interspersed light/dark sub-cycles to simulate thermal shock effect occurring in natural exposures

Step 1 – 240 min dark/spray 40°C, 95% RH

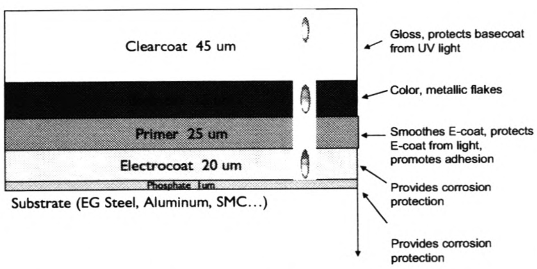
- Time needed to produce maximum water uptake to match worst case S. Florida scenario for rainfall and condensation
- Replicates migration of low Mw components over time
- Time required to achieve water permeation to electrocoat and to produce delamination failures

Water Verification Step 1

- Minimum 4-5% water uptake required in coating system tested to guarantee permeation into electrocoat



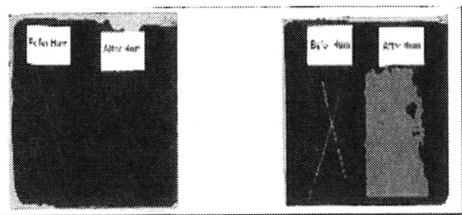
Water Migration Step 1



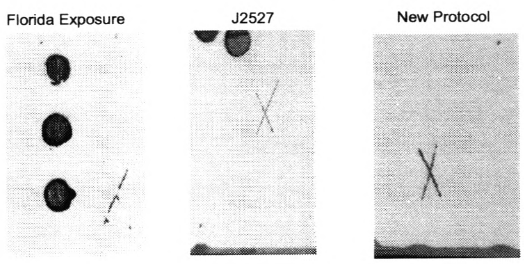
Horizontal tester likely to provide more efficient water uptake

Delamination – new vs current Protocol

- Systems with overall thinner coating layers and higher UV light transmittance more susceptible to this failure mode



Fine Detection of Adhesion Failure due to step 1



Example of adhesion test showing correlation to Florida exposure (failure after two years) while SAE J2527 test indicated a "false positive"

Step 2 – 30 min light 0.4 W/m2, 50°C, 50%RH

- Weather data indicates water is out of coating layers before the UV reaches the maximum intensity outdoors

Date Time	Rain (in)	Panel Temp (°F)	Amb Temp (°F)	Ambiant Dew Point (°F)	Ambiant RH (%)	Load Cell (g)	Sun Solar Radiation (W/m	Rain pH
7/4 9:23	0	110.16	82.93	74.93	76.75	29.23901785	414.4	6.3639974
7/4 9:28	0	114.61	83.67	75.64	76.75	27.87992639	444.4	6.3429182
7/4 9:33	0	111.91	83.67	75.64	76.75	25.38039149	468.1	6.3429182
7/4 9:38	0	112.8	83.87	75.84	76.75	23.34780532	473.1	6.3429182
7/4 9:43	0	117.38	83.67	74.88	74.75	22.69827375	488.1	6.3429182
7/4 9:48	0	123.7	84.38	75.94	76.75	21.92742391	563.1	6.3429187
7/4 9:53	0	117.38	84.38	76.34	76.75	19.9487236	526.6	6.3200824
7/4 9:58	0	118.32	84.38	75.74	75.75	17.86573664	539.4	6.3200824
7/4 10:03	0	122.7	84.78	74.73	72.75	16.31099177	555.6	6.3200824
7/4 10:08	0	121.21	84.38	74.63	73.25	14.11965882	563.1	6.3200824
7/4 10:13	0	124.7	85.1	76.24	74.75	13.27391391	576.9	6.3200824
7/4 10:18	0	132.7	85.83	75.7	71.75	12.50841161	583.1	6.3200824
7/4 10:23	0	136.2	86.55	75.22	69.25	11.22779081	585.6	6.3200824
7/4 10:28	0	128.4	86.55	75.73	70.25	8.393880295	624.4	6.2200824
7/4 10:33	0	131.6	85.83	74.2	68.25	5.789188677	685.6	6.3200824
7/4 10:38	0	123.7	85.83	73.53	66.75	3.682089745	664.4	6.3200824
7/4 10:43	0	129.4	85.83	73.98	67.75	3.952825811	718.8	6.2930037
7/4 10:48	0	128.3	85.83	74.63	69.25	2.104865169	683.1	6.3200824
7/4 10:53	0	123.2	85.83	73.53	66.75	2.192716555	689.4	6.3200824
7/4 10:58	0	133.9	85.83	73.53	68.75	0.854613633	693.1	6.3200824

Verification of Coating Water Removal

Measurements from Coating Water Removal Experiments

Initial weights

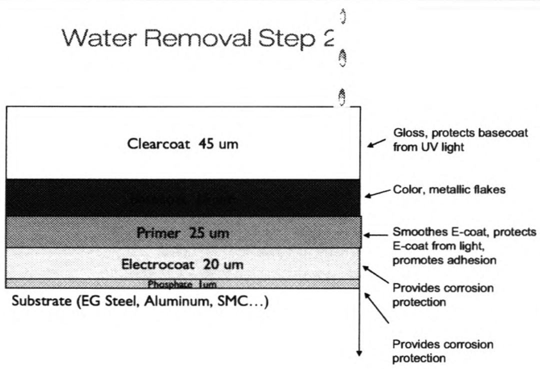
Wm #12 (CI5000)	Wm #13 (Q-Sun)
62.4362	63.0762

Completed weights

Wm #12 (CI5000)	Wm #13 (Q-Sun)
62.4308	63.0662

Data shows drying in both types of weathering equipment

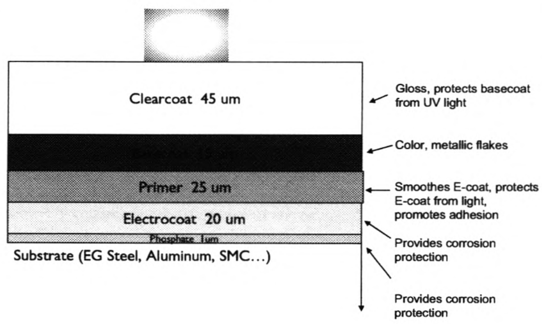
Water Removal Step 2



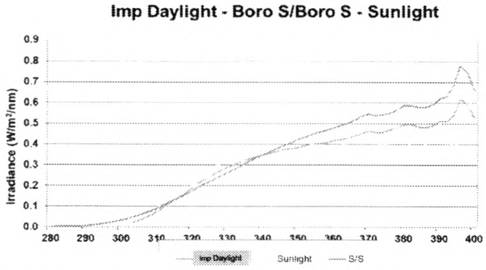
Step 3 – 270 min light, 0.8 W/m2, 70°C, 50% RH

- This step, as in all light steps, uses an improved daylight filter
- The new filter allows higher irradiance/ UV exposure and accelerates protocol over SAE J2527
- Improves match to gloss and color fade data as compared to S. Florida exposure
- Irradiance Limitations are ability to maintain high temperatures without a chilling device and producing same degradation chemistry as is seen outdoors

Light Step 3

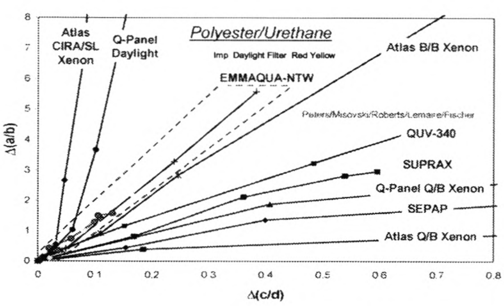


Improvement in SPD of the Imp Daylight Filter



Type S Boro/Type S Boro filter combination (aka "Daylight") was an improvement, but still allowed short wavelength UV exposures. A new filter system represents current state-of-the-art spectral UV match

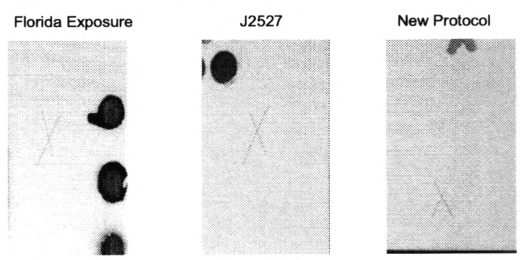
Proper Chemistry change using Imp Daylight Filter at 0.8 W/m2



"Chemistry" of Photo-degradation

- Many different accelerated weathering tests and standards exist today with different filter combinations and light exposure up to 23 suns
- Requirements necessary to validate these tests:
  - Prove "chemistry" of failure matches outdoor
  - Prove ability to duplicate all known failure modes
- Continue to test in field to validate accelerated results

Test Method Development Results

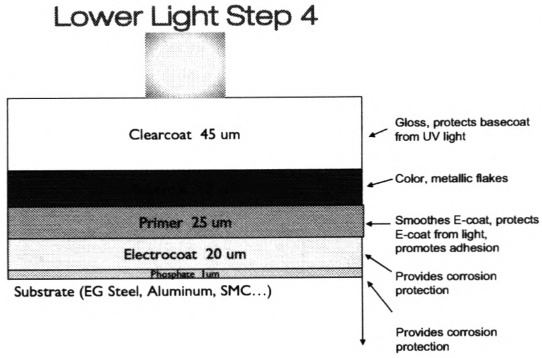


Example of correlation of good weathering performance as well as accelerated weathering methods despite change in filter and increased irradiance

Step 4 – 30 min light 0.4 W/m2, 50°C, 50% RH

- Allows gradual cooling and stress relief of coating as to replicate early evening condition outdoors
- Prevents unnatural mechanical changes from occurring during the accelerated weathering process
- Short time frame as not to lose a significant amount of acceleration
- Irradiance could be set lower, but it lessens acceleration and shows no advantage in correlation to outdoor results

Lower Light Step 4



Example of Early Morning Solar Radiation

Date Time	Rain (in)	Panel Temp (°F)	Amb Temp (°F)	Ambient Dew Point (°F)	Ambient RH (%)	Load Cell (g)	Sun Solar Radiation (W/m	Rain pH
7/4 9:23	0	110.16	82.95	74.95	76.75	29.23801785	414.4	6.3639374
7/4 9:28	0	114.61	83.67	75.64	76.75	27.87952636	444.4	6.3429182
7/4 9:33	0	111.91	83.67	75.64	76.75	25.38039149	468.1	6.3429182
7/4 9:38	0	112.8	83.67	75.94	76.75	23.34780530	473.1	6.3429182
7/4 9:43	0	117.38	83.67	74.83	76.25	22.86627529	488.1	6.3429182
7/4 9:48	0	123.5	84.38	75.94	75.25	21.62942391	502.1	6.3429182
7/4 9:53	0	117.38	84.38	76.34	76.75	19.1487794	532.5	6.3200824
7/4 9:58	0	118.37	84.38	75.74	75.25	17.06573964	539.4	6.3200824
7/4 10:03	0	122.2	84.38	74.73	72.75	16.31059137	556.6	6.3200824
7/4 10:08	0	121.21	84.38	74.93	73.25	14.11965082	553.1	6.3200824
7/4 10:13	0	124.7	85.1	76.24	74.75	13.27381391	576.9	6.3200824
7/4 10:18	0	132.7	85.83	75.7	71.75	12.50841161	583.1	6.3200824
7/4 10:23	0	136.2	86.55	75.32	69.25	11.22779061	585.8	6.3200824
7/4 10:28	0	128.4	86.55	75.75	70.25	8.292880295	624.4	6.3200824
7/4 10:33	0	131.6	85.83	74.2	68.25	5.789168677	685.8	6.3200824
7/4 10:38	0	123.2	85.83	73.53	66.75	3.602089745	664.4	6.3200824
7/4 10:43	0	129.4	85.83	73.98	67.75	3.952925811	715.6	6.2990032
7/4 10:48	0	126.3	85.83	74.83	69.25	2.104985169	683.1	6.3200824
7/4 10:53	0	123.2	85.83	73.53	66.75	2.192716955	689.4	6.3200824
7/4 10:58	0	123.9	86.83	73.93	66.75	8.984613633	693.1	6.3200824

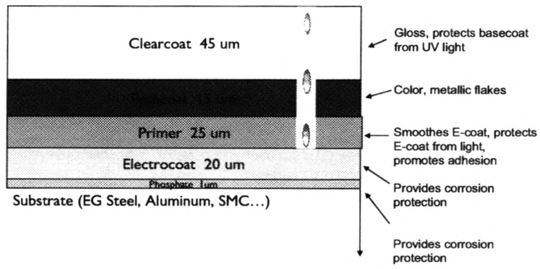
Example showing maximum Solar Radiation

Date Time	Rain (in)	Panel Temp (°F)	Amb Temp (°F)	Ambient Dew Point (°F)	Ambient RH (%)	Load Cell (g)	Sun Solar Radiation (W/m	Rain pH
7/3 16:23	0	136	88.74	73.72	61.26	-0.378986092	794.4	6.4061668
7/3 16:28	0	129.4	88.74	76.16	64.26	-1.091478812	781.8	6.4061668
7/3 16:33	0	128.4	88.01	73.62	62.26	-1.180203684	786.9	6.4061668
7/3 16:38	0	131.6	88.01	74.46	64.26	0.066813406	824.4	6.4061668
7/3 16:43	0	123.2	88.01	73.62	62.26	-0.467602043	843.1	6.4061668
7/3 16:48	0	123.2	88.01	73.62	62.26	-0.646422413	830.6	6.4061668
7/3 16:53	0	133.9	86.74	73.72	61.26	-0.656046212	873.1	6.4061668
7/3 16:58	0	130.6	88.74	73.97	61.76	-0.912289497	909.4	6.4061668
7/3 16:03	0	117.38	88.01	73.28	61.76	-1.805661709	286.6	6.4061668
7/3 16:08	0	106.89	87.28	74	64.76	-0.823640916	166.9	6.4061668
7/3 16:13	0	92.46	86.66	73.31	64.76	-1.637190046	16.9	6.4061668
7/3 16:18	0	86.83	86.1	70.78	62.26	-1.806681709	9.4	6.427236
7/3 16:23	0.33	73.16	81.63	74.34	78.76	24.24406318	3.1	6.6810934
7/3 16:28	0.34	72.46	77.31	73.62	88.26	44.87468676	6.9	4.6066408
7/3 16:33	0.43	72.46	74.63	72.67	93.76	38.23019046	21.9	4.7336726

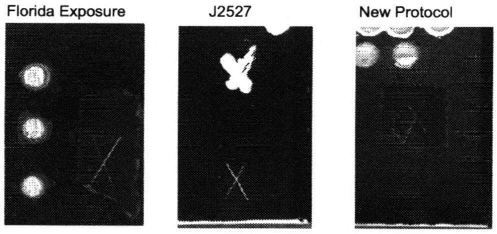
Step 5 – 150 min dark/spray 40° C, 95% RH

- Combines with step 6 to provide another long water exposure period
- While water may migrate to the electrocoat over this time period, this step represents a lighter rainfall or condensation event
- Step is still significant in producing basecoat/clearcoat delamination failures

Water Migration Steps 5-6



Delamination failure expected from Step 5



Water exposure aids in mechanical failure of BC/CC interface

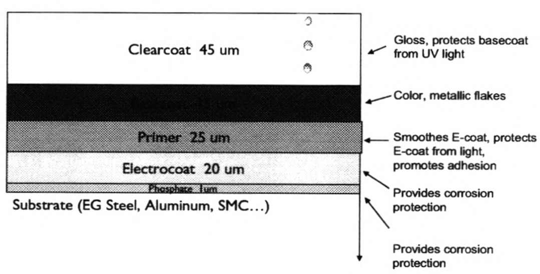
Steps 6-9 Mechanical Cycling Segment

- Necessary to produce viscoelastic effects on coating systems
- The fast changes in exposure condition can be especially effective in producing cracking failures
- These steps are repeated 3 times to provide enough changes to create failures as seen in a S. Florida environment
- Combined with steps 1-5 better at detecting cracking failures than SAE J2527

Step 6 – 30 min dark/spray 40° C, 95% RH

- 1st time through cycle aids with step 5 in providing water penetration into the basecoat and primer layers
- 2nd and 3rd time through cycle represents a very short rain or condensation event, where water permeates only into the clearcoat layer
- Expansion of the clearcoat in this fashion in relationship to the other coating layers provides a good ability to detect micro cracking

Water Migration Step 6



Step 7 – 20 min light 0.4 W/m2, 50°C, 50%RH

- Similar to step 2
- Again step designed to remove water from the coating before higher irradiance light cycle
- Less time required for step since water only needs evacuation from the clearcoat layer

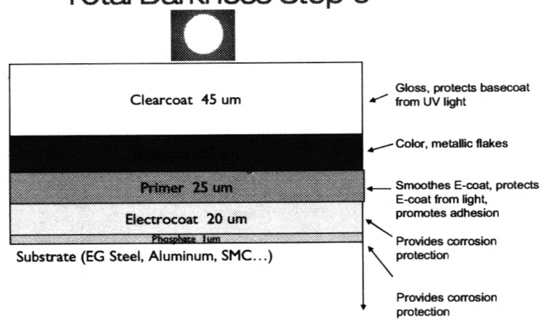
Step 8 – 120 min light, 0.8 W/m2, 70°C, 50% RH

- Longest portion of mechanical cycle – designed still to maximize acceleration while maintaining the proper failure chemistry
- Use of the imp daylight filter again allows a better overall correlation to S. Florida related UV effects

Step 9 – Dark no spray 40°C, 50% RH

- A true "stress relief" step, where the coating approaches a stead state condition
- Relates to a later evening condition where the sun is setting and before condensation could potentially start
- Failure to provide the "stress relief" step typically leads to a higher probability of an unnatural cracking failure

Total Darkness Step 9



Example of Step 6-9 Coating Effects

J2527 Test | New Test Cycle | Florida Exposure

Applications

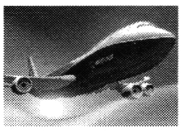
- Protocol improves results with not only steel, but on plastic and aluminum substrates
- Correlation improvement also noted on performance of aircraft coatings (Boeing)
- Protocol Development work could be done for other coating applications (decks, house paint, etc.)

Use in Auto Industry

- Critical for use in integrated process applications
- Industry trends toward thinner overall film thickness
- Improved for detecting mechanical failures with multiple coating repairs
- Improved for determining "real" color fade performance of new pigments

Protocol Status

- New ASTM Method Issued D-7869
- Multiple OEM's expected to adopt new method and revise test specifications
- Expect the test methodology to evolve into other industries



Thank You For Your Time

Questions??