UV HARDCOAT TECHNOLOGY: VISION OF FUTURE POSSIBILITIES IN IMPROVING VEHICLE DURABILITY

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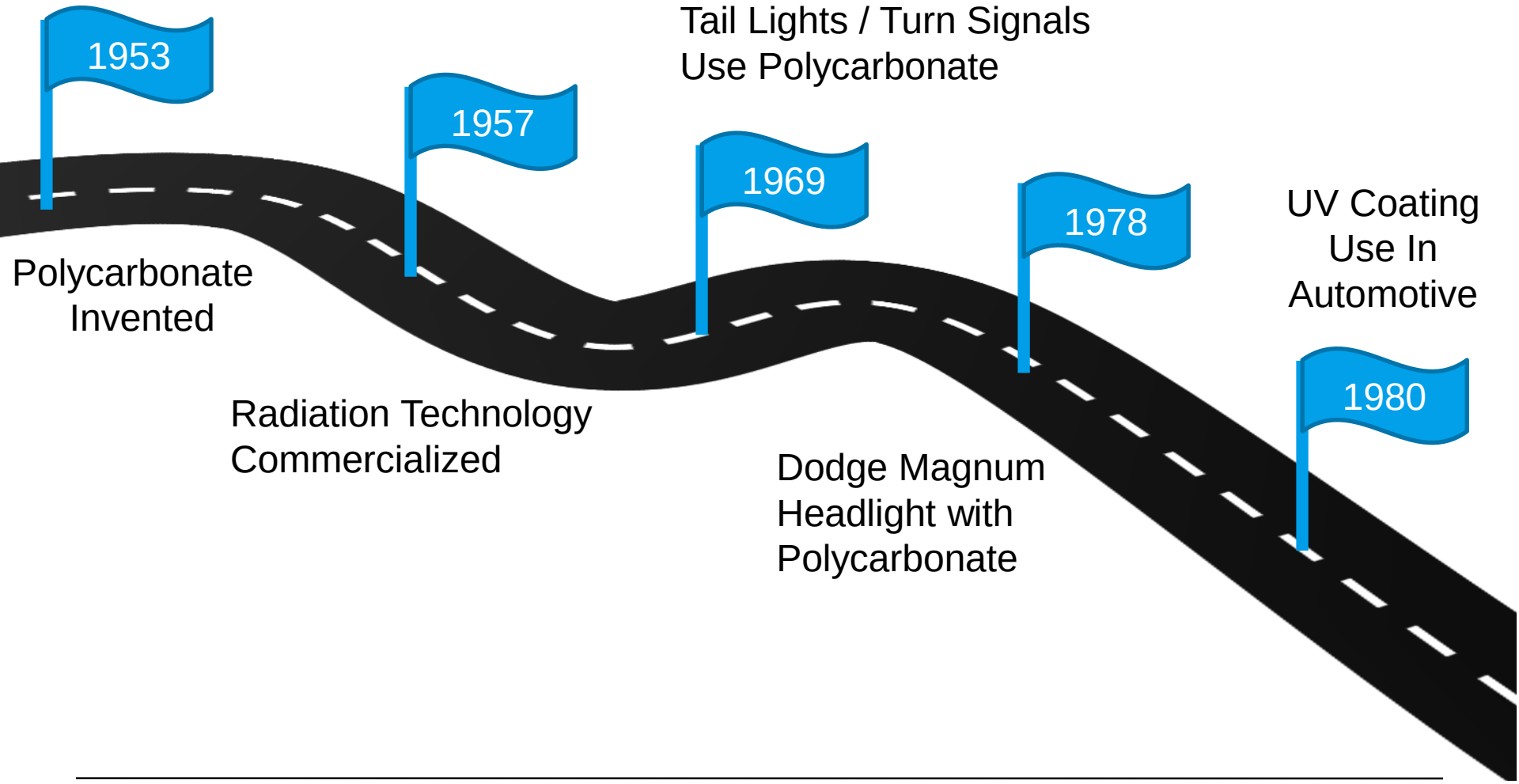
UV/EB Leading the Way for the Future of Automotive

Radiation Cure Technology

- UV Curable Coatings Use in Automotive Applications
- Benefits and Potential Challenges of UV Coatings
- UV Exterior Performance Testing
- Interior Automotive Trends
- UV Interior Performance
- Dual Cure Technology

Introduction of UV Coatings in Automotive Applications



UV Mechanism Simplified

Light Source
(UV Energy – mJ/cm^2)

PI
Photoinitiator

PI*
Free Radicals

Oligomers and Monomer
(Liquid)

Highly Cross-linked
Polymer Network
(Cured Film)

Benefits of UV Curable Coatings

- Rapid Cure
- Shorter Process Time / Smaller Line Foot Print
- Less Dirt Exposure – Less Contamination
- Flow Coating is Possible
- Complete Cure – No Post Cure
- Instant Packaging
- Lower Film Thickness Requirement
- Increased Cross-Link Density
- Superior Chemical Resistance
- Improved Scratch Performance
- Higher Solids Capable – Lower VOC
- Lower Energy Consumption
- Potential to Reclaim or Recycle

UV Challenges

- Cure is Line of Sight – Shadowed Areas Will Not Cure
- Can be Overcome by Light Positioning
- High Cross Link Density Does Not Lend Itself to Recoat or Second Time Repair
- Low First Time Quality Issues Can Lead to High Scrap
- Flaking on Masking
- Line Design Can Minimize Concerns
- Low Viscosity Nature Can Cause Sagging Concerns on Complex Parts
- UV Cure Parameters Can Cause Heat Distortion on Low HDT Substrates Such as ABS
- Line Design and Lamp Choice Can Minimize Issues
- 2K Basecoat Formula is Critical in 2 Coat Systems

Chemical Resistance Requirements for Lighting Applications

OEM	Test Method	Condition	Result
GM	GMW14334	Rain-X-Immersion x 1 Hour	Pass
		Glass Cleaner Immersion x 1 Hour	Pass
		Simple Green Cleaner x 24 Hours	Pass
Ford	WSSM80J6A	Bug and Tar Remover x 48 Hours	Pass
		Motor Oil, 5W30 x 48 Hours	Pass
FCA	463PB3101	Unleaded Gasoline with X-Scribe x 24 Hours	Pass
		Windshield Washer Fluid with X-Scribe x 24 Hours	Pass
		Anti-freeze (50/50) with X-Scribe x 24 Hours	Pass
HKMC	MS652-14	Sulfuric Acid (0.1N, 0.2ml) x 24 Hours	Pass
		Sodium Hydroxide (0.1N, 0.2ml) x 24 Hours	Pass

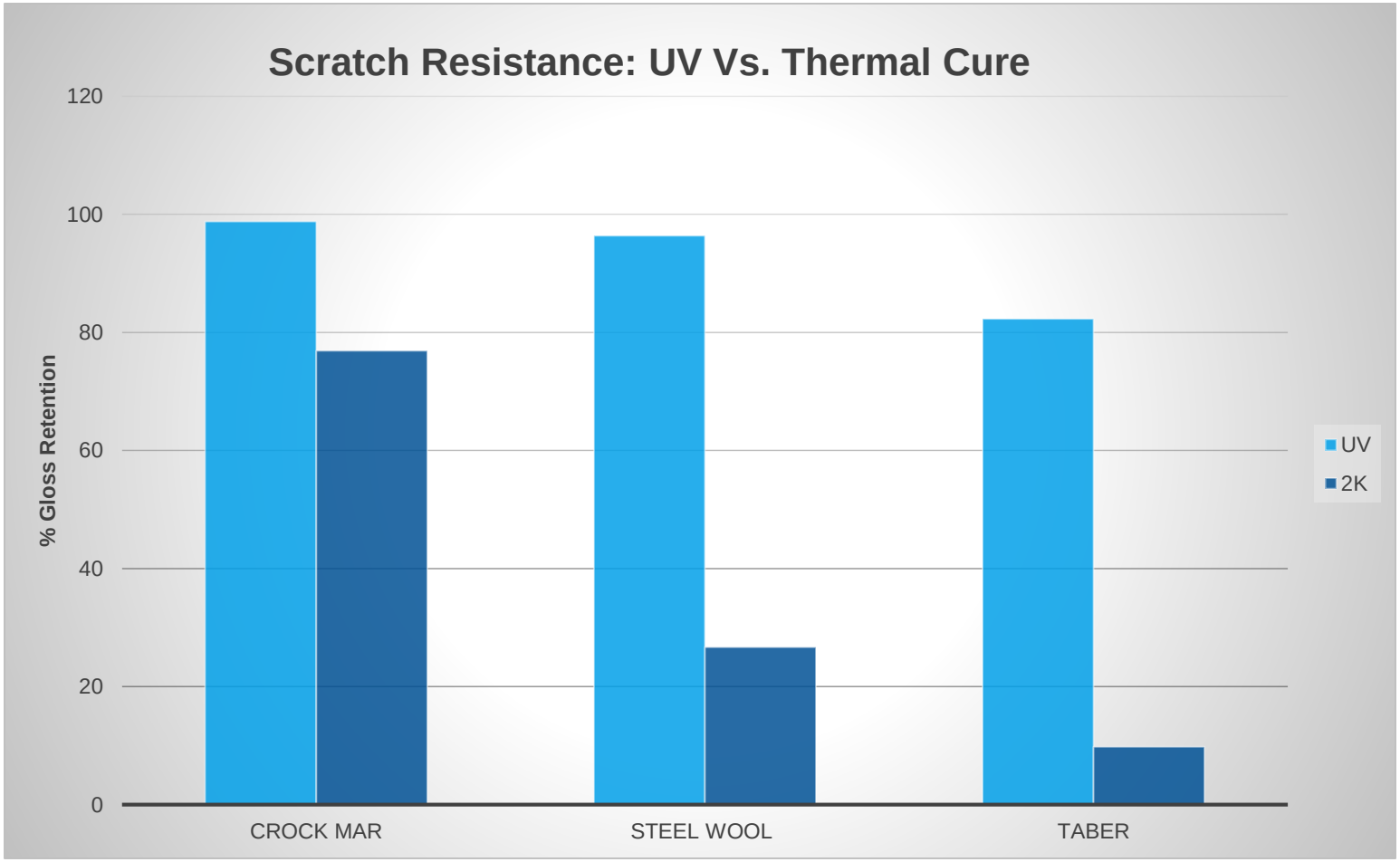
Scratch Requirements for Lighting Applications

FORMULATION	TABER ABRASION CS10F x 500 CYCLES	CAR BRUSH APPARATUS 20 CYCLES	STEEL WOOL 10 DOUBLE CYCLES
Gen IV	23%	20.3%	1.6%
Gen V	9%	13.3%	0.1%

AMTEC KISTLER CAR WASH APPARATUS

TABER ABRASION CS-10F WHEEL

Comparison of UV Vs. Thermal Performance



Interior Automotive Trends

OEMs have strong desire for improved scratch and abrasion resistance for interior application especially for piano black appearance

Global regions have different opinions and at different stages

Dual Cure technology is fairly well established in Europe

Asia has been using UV systems for several years

North America gaining interest, but finisher capabilities limited

Initially, some OEM specified exterior UV hardcoat technology for interior applications

Issues with this approach:

- Exterior coating over engineered and high cost for interior application
- Energy requirement for exterior grade coatings much higher and not good match for lower HDT plastics or dark color plastics
- **Thermal expansion differences between traditional hardcoat and targeted interior plastics**

Conclusion: it is better to design a coating specifically to meet the requirements of interior application

Interior Demands and Technology Approaches

- Piano Black / Chrome Finishes Driving Improvements in Chemical and Scratch / Abrasion and Resistance
- Key Performance Criteria Varies by OEM – Many Similarities and Overlap
- Larger Focus on Improving Micro-scratch
- Research Dedicated on Investigating the Best Test Method for Reproducing and Testing Field Related Concerns Especially in High Touch Areas

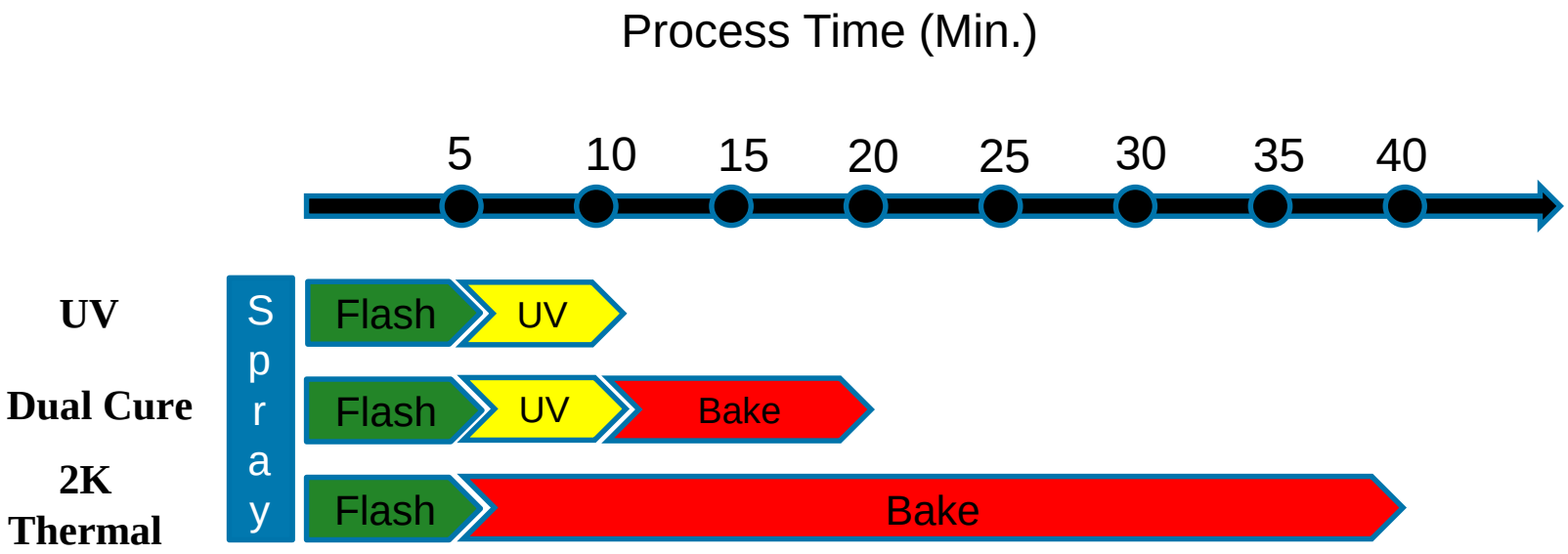
Varying Options to Achieve Similar Appearance With Improved Performance

Asia: 2K Basecoat + UV Clear Topcoat

North America: MIC or 2-shot PC + UV Clear Topcoat

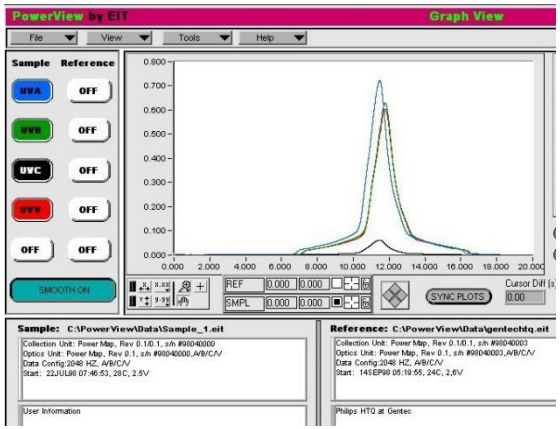
Europe: MIC or 2K Basecoat + Dual Cure Clear / Tinted Topcoat

Technology Process Time Comparison



UV Recommended Processing

Environ. Temp.	25 ± 5 °C (77 ± 9 °F)
Relative Humidity	45 – 65%
Film Thickness	14 – 22 microns
Ambient Flash	Approximately 1 – 2 min.
Flash Time	2-3 min IR or 5-7 min. conventional
Flash Temp.	65 – 72 °C
UV Cure	Intensity >150 mW/cm^2 Energy 1.5 – 3.0 J/cm^2



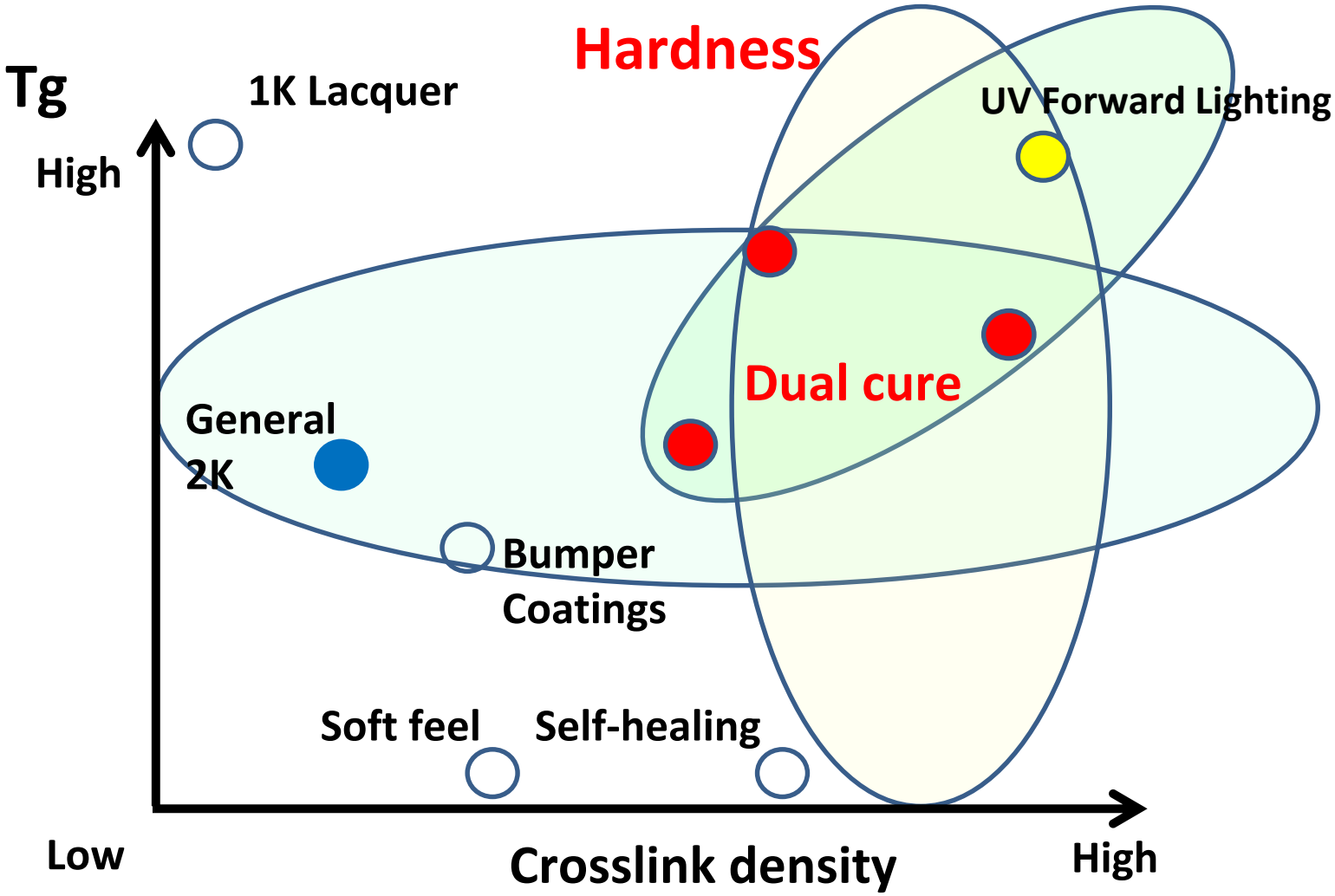
UV Interior Performance: Scratch and Mar

Condition	Result
Taber Abrasion (CS10, 500 gr. x 1,000 Cycles)	Pass
Five Finger Scratch (1mm tip) 13 N	Pass
Sunscreen + Insect Repellent 1 hr @ 80°C	Pass
Post Five Finger Scratch (1mm tip) 8 N	Pass
Oven Aging @ 95°C x 168 Hrs	Pass
Post Five Finger Scratch (1mm tip) 13 N	Pass
Resistance to Scuffing (Head A, 0.9 Kg Load) x 1,000 Cycles	Pass
Dry Crockmeter x 150 Cycles	Pass
Crockmeter x 10 Cycles (3M Polishing Paper) Gloss Retention	97.40%
Friction Resistance – Petroleum Benzene (200 gr. x 200 Cycles	Pass
Steel Ball (1Kg) Impact: -30°C x 4 Hrs at 50 cm Drop Height	Pass

UV Interior Performance: Chemical Resistance

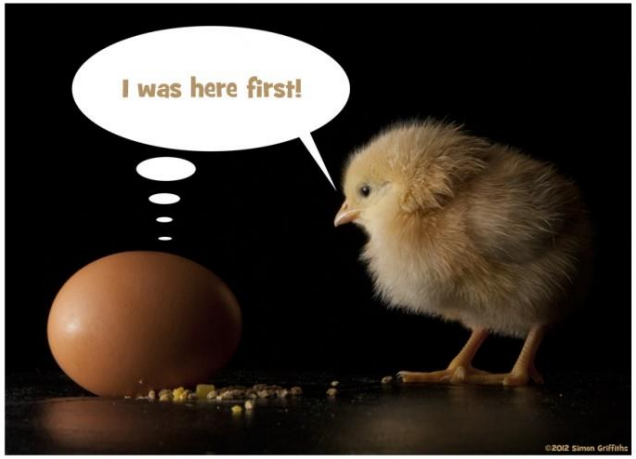
Condition	Result
Suntan Lotion (SPF 30) 23°C x 24 Hrs w/ Crock Cloth	Pass
Suntan Lotion (SPF 30) 74°C x 1 Hr w/ Crock Cloth	Pass
Insect Repellent (Deep Woods Off) 23°C x 24 Hrs w/ Crock Cloth	Pass
Insect Repellent (Deep Woods Off) 74°C x 24 Hrs w/ Crock Cloth	Pass
Acid Perspiration Immersion 70°C x 24 Hrs	Pass
Alkaline Perspiration Immersion 70°C x 24 Hrs	Pass
Sodium Chloride Solution Immersion 70°C x 24 Hrs	Pass
Windex, Fantastik, Armor All, Formula 409: 10 Double Rubs	Pass
Window Cleaner Spot (windex), 0.25 ml x 1 hr	Pass
Air Freshener	Pass
Fogging Test 100°C x 3 Hrs	Pass

Dual Cure: Balance Between Crosslink Density and Hardness



Conclusion

Chicken or the Egg



- Scratch Resistance Improvements Possible Through UV or Dual Cure Technology Approaches
- Effective Change of Current Status Quo:
  - Tier One Apprehension of Capital Investment Prior to Market Realization
  - Needed Collaboration Between OEM and Tier One for Successful Implementation