Meeting at OICA

Plastic Glazing overview

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  7- Weathering
  8- Adhesion
Exatec, SABIC Innovative Plastics
Advanced Glazing Technology

- Materials
- Processes
- Coatings
- Secondary operations

SABIC, an industry leader

- One of the largest producers of polycarbonate and other thermoplastic materials

- A global resource
  - SABIC operates in 40+ countries
  - SABIC manufactures on a global scale in the Americas, Europe and Asia Pacific
  - 6 dedicated Technology & Innovation Centers in Saudi Arabia, Europe, the USA and India
  - 33,000 employees
Exatec – SABIC Innovative Plastics Advanced Glazing Technology

- 12 year leadership developing resins, coatings, part design and manufacturing technologies for automotive glazing

- A wide range of enabling technologies for polycarbonate glazing systems - including the Exatec glass-like plasma coating

- 9,300 sq. m Glazing Technology Development Center in Michigan, USA

- Globally connected teams with localized application and development support

Enabling Automotive Industry Adoption of Polycarbonate Glazing
Wetcoated or Wetcoated & Plasma
Lexan* Polycarbonate everywhere you need performance
Side Window – Backlite – Roof

In-production examples:

GM Corvette targa roof
Lexan with AS4700 coating
Tier: Lexamar (Magna USA)

Honda Civic lower rear
Lexan with AS4700 coating
Tier: Freeglass (Germany)

SEAT Leon RQW
Lexan with AS4000 coating
Tier: Freeglass (Germany)

Daimler bus operator shield (Toronto)
Lexan with Exatec E900 plasma
Parts coated at Exatec
AS2 production

Advanced styling, weight reduction
and impact resistance beyond glass...
2009 Production at Exatec: Daimler Bus: Driver Protection Shield
City of Toronto Transit Commission

AS2 Requirement for driver visibility
Taber® Abrasion 1000 cycles

Plasma over wet coat systems (Exatec® E900 or similar) with Lexan* Polycarbonate

Wet coat systems AS4700\(^\dagger\) or similar with Lexan* Polycarbonate

Next gen. primer and wetcoat advancements in development

\(^\dagger\)Momentive Performance Materials

Exatec plasma: Glass-like Abrasion Resistance
Primer/Wet coat: UV protection
Substrate: (Lexan PC resin)

Abrasin performance - difference of coatings
Plasma Process Relationships

To optimize performance, must understand above relationships

**Plasma Process**
- Plasma source settings
- Process gas flow rates
- Chamber environment (P,T)

**Plasma Chemistry/Coating Properties**
- Thickness
- Chemical properties
- Physical properties
- Optical properties

**Performance**
- Abrasion (Taber®, wiper)
- Weathering
- Car Wash
- Adhesion
- Other

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**EXATEC**
inspiring glazing technology
Wixom Plasma LINE UPGRADE

- State-of-art pump system (ULVAC Technology) ➔ INDUSTRIALIZATION FOR MASS PRODUCTION
- Additional process controls ➔ PROCESS STABILITY
  - Pressure
  - Temperature
  - Line speed
  - Integrated SPC
- Design for robustness ➔ EASE OF MAINTENANCE
- Modular design ➔ EXPANDABLE AS NEEDED

Expanded plasma coating design space ➔ improved performance
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- **Exatec test capabilities overview**
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Performance Testing and Validation

Exatec features a full service lab and testing capability focused on advance polycarbonate glazing technology through sample testing, in-house prototype and product certification and assisting in the development of polycarbonate glazing tests and specifications.

Capabilities include:

**Weathering Testing**: natural exposure, accelerated weathering and thermal cycling

**Coating Systems Performance**: adhesion, bonding/adhesives, and abrasion

**Analytical**: Non-destructive testing and analysis

**Dedicated scratch and abrasion** lab and team to study fundamentals of scratch damage mechanisms on coatings Lab-Scale Wiper Test Equipment, Part of Exatec’s Scratch and Abrasion Evaluation Capabilities.
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Taber® Abrasion

The Taber® Test is used to check compliance with regulatory scratch and abrasion performance standards. It should be performed using the most current ASTM D1044 protocol.

Following factors should be tightly controlled when performing this test:

- Temperature and humidity
- Wheel mounting
- Vacuum suction force and height
- Refacing stone type and usage
- Between-sample time interval
- Sample cleaning
- Haze-meter and sample holder
- Machine calibration and verification

http://www.cs-10f.com/
**Brushing of the wheel**

**IMPORTANT:** It has been observed that debris may adhere to the side of the CS-10F wheel and dislodge during testing. To eliminate this as a potential source of variation, Taber Industries recommends using a soft bristle, anti-static brush (e.g. Taber p/n 132616). After resurfacing the wheels on the ST-11 refacing stone, gently pass the brush along the side of the wheels to remove any loose particulate material. [August 1, 2007]*

**Vacuum height and opening**

The modification requires the vacuum pick-up nozzle openings to be enlarged from 8 mm (0.313 in) to 11 mm (0.438 in). 

* [www.cs-10f.com](http://www.cs-10f.com)
# Bristle Abrasion Testing

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Amtec Kistler</th>
<th>Exatec</th>
<th>ISO 20566:2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number/Max dimensions of test panels</td>
<td>4 / 305 x 155 mm (max 1 x 610 x 310 mm)</td>
<td>2 / 50 x 100 mm (max 1 / 100 x 100 mm)</td>
<td>not specified</td>
</tr>
<tr>
<td>Test panel thickness</td>
<td>1.5 - 3.5 mm</td>
<td>any</td>
<td>not specified</td>
</tr>
<tr>
<td>Speed of sample holder</td>
<td>3-10 m/min</td>
<td>6 cycles per minute (brush moves not samples)</td>
<td>5 ± 0.2 m/min</td>
</tr>
<tr>
<td>Number of double passes</td>
<td>1-99</td>
<td>not specified</td>
<td>10 double passes</td>
</tr>
<tr>
<td>Number of spray nozzles</td>
<td>2</td>
<td>1 at top of brush</td>
<td>2</td>
</tr>
<tr>
<td>Water container capacity</td>
<td>120 L</td>
<td>20 L</td>
<td>not specified</td>
</tr>
<tr>
<td>Qty of silica flour per liter of water</td>
<td>2.0 g max</td>
<td>1.0 g</td>
<td>1.5 g (mean particle size = 24 µm)</td>
</tr>
<tr>
<td>Water temperature</td>
<td>~7 L</td>
<td>500 ml/min</td>
<td>2.2 ± 0.1 L/min</td>
</tr>
<tr>
<td>Water consumption/test cycle</td>
<td>2.2 ± 0.1 L/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brush width</td>
<td>400 mm</td>
<td>165 mm</td>
<td>400 mm</td>
</tr>
<tr>
<td>Brush direction of rotation</td>
<td>clockwise / counter-clockwise</td>
<td>clockwise moving left to right</td>
<td>opposite to direction of travel of test panel holder</td>
</tr>
<tr>
<td>Brush RPM</td>
<td>50 - 127 min^{-1}</td>
<td>Not specified</td>
<td>~120 min^{-1} opposite to direction of travel of test panel holder</td>
</tr>
<tr>
<td>Bristle length</td>
<td>440 mm</td>
<td>160 mm</td>
<td>440 mm</td>
</tr>
<tr>
<td>Penetration depth</td>
<td>100 mm</td>
<td>not specified</td>
<td>100 mm</td>
</tr>
<tr>
<td>Bristle material</td>
<td>PE, X-profile 0.8mm</td>
<td>PE, X-profile 0.8mm</td>
<td>PE, x-shaped, spliced, 0.8mm</td>
</tr>
</tbody>
</table>

## Graphs

- **Graph 1:** Comparison of Average of Delta Average Haze over test cycles for different coating types.
- **Graph 2:** Scratches, Roughening on test panels.
Oscillating Sand Test

- ASTM F735
  - determines the resistance of transparent plastics and transparent coatings utilized in windows or viewing ports, to surface abrasion using oscillating sand.
  - The specimen holder shall have a cutout approximately 100 by 100 mm
  - A variable power supply shall be utilized to control the abrader motor to operate at 300 strokes per minute.
  - The sand shall be quartz silica, graded 4/10
  - New sand shall be used for each specimen tested.
  - Standard: Subject the specimen to 100, 200, 300, and 600 strokes.
  - Exatec modification: 1200 strokes

Other abrasion tests exist...

Oscillating Sand

Combination of scratches, pitting and roughening
Falling Sand Abrasion

Abrasion testing with an impact-based component

Reference: DIN 52 348, ASTM D968 Method A

- 3 Kg of specified sand (class 0.5/0.7 mm) are trickled through a down pipe toward the test specimen surface.
- All probes are located on a dial, which has an angle of 45 degree to the falling sand axis (= down pipe axis).
- The measurement category is the increase in light scattering (detected in transmission).

Impact abrasion performance is possibly more realistic for what a windscreen would experience
Scratch and Abrasion Evaluation Technology

Measure, test, differentiate and prevent surface damage to polycarbonate glazing

Dedicated team to study fundamentals of scratch damage mechanisms

- Taber®
- Wiper
- Surface wipe
- Car wash

Lab Scale Measurement

Taber abrasion  Lab scale wiper  Full-scale wiper stands

3+ year fleet data (Michigan, USA)

Develop specifications for wiper and abrasion performance

⇒ Drives Next-Generation coatings development
Accelerated Wiper Testing

Testing Conditions
- Slurry Solution: 5% NaCl and 2.5% ASTM dust in DI water
- Slurry Flow Rate: 90 ml/min
- Wiper weight: 15 to 25 g/cm
- Wiper velocity: 10 to 23 cm/s
- Wiper Cycles: 25,000

Exatec® E900 coating is insensitive to variations in wiper load & velocity

Load varies across wiper length and from vehicle to vehicle

Velocity varies across the wiper path

Exatec E900 Coating is insensitive to variations in wiper load & velocity
Wiper Abrasion of Siloxane Wet Coating and Exatec® E900

Nano-Profilermetry

50/50 Sample

<table>
<thead>
<tr>
<th>Siloxane Wet Coating</th>
<th>Exatec® E900</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.61%</td>
<td>0.03%</td>
</tr>
</tbody>
</table>

Higher density of scratches in wet coating than Exatec® E900

Greater haze increase in wet coating than Exatec® E900

Exatec® E900 with PECVD Coating has superior Wiper Abrasion Performance over Siloxane Wet Coatings alone
Ductility: Results

Similar to ASTM D 3763 Standard Test Method for High Speed Puncture Properties of Plastics

12.6mm Diameter Hemispherical Impact Head

2.27 kg Drop weight

Sample pneumatically clamped around the perimeter of a 76.2 mm diameter circular opening.

Impact velocity measured just prior to impact

Load and elapsed time measured during impact

Deflection & energies calculated.

Cold temperature impacts are conducted by chilling the samples over four hours at temperature. A sample is removed from the chamber and impacted within 30 seconds of removal.

<table>
<thead>
<tr>
<th>Steel Ball</th>
<th>Temp</th>
<th>Drop Meters</th>
<th>Impact Energy (Joules)</th>
<th>Uncoated Lexan® Polycarbonate</th>
<th>Exatec® E900 coated Polycarbonate</th>
</tr>
</thead>
<tbody>
<tr>
<td>227 g</td>
<td>-40C</td>
<td>9.1</td>
<td>20.3</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
<tr>
<td></td>
<td>23C</td>
<td>17.7</td>
<td>39.3</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
<tr>
<td>2270 g</td>
<td>-40C</td>
<td>9.1</td>
<td>194</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
<tr>
<td></td>
<td>23C</td>
<td>17.7</td>
<td>376</td>
<td>No Cracks</td>
<td>No Cracks</td>
</tr>
</tbody>
</table>

PC Based Samples Behaved in a Ductile Manner
Weathering: Important Factors relating to PC Degradation

Factors that Significantly Affect PC Degradation

Wavelength of Light: PC degradation rate depends on wavelength of light and filter cut-off.

Temperature

Factors that have No Significant Affect on PC Degradation

Thermal Aging or Dark Cycle Test

Humidity

Water spray/wiping: affects gloss loss and surface erosion for uncoated samples, but none on degradation yellowing

Light intensity
Weatherability of coated PC: 3 Types of Failure seen

Micro cracking

Delamination

Yellowing

Microcrazing: noticeable by the naked eye is another mode of failure.

Delamination: coating delaminates from the PC.

Yellowing: measured as a YI value.

First optical defect is determined to be a failure
**Recommended Weathering Protocol**

<table>
<thead>
<tr>
<th>Source</th>
<th>Modified ASTM G155 cycle 1</th>
<th>ASTM G155 Cycle 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>Atlas Ci5000</td>
<td>Atlas Ci5000</td>
</tr>
<tr>
<td>Inner Filter</td>
<td>borosilicate</td>
<td>borosilicate</td>
</tr>
<tr>
<td>Outer Filter</td>
<td>borosilicate</td>
<td>borosilicate</td>
</tr>
<tr>
<td>Cycle Modes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Cycle 1</td>
<td>Light and Dry</td>
<td>Light and Dry</td>
</tr>
<tr>
<td>Time (min)</td>
<td>102</td>
<td>102</td>
</tr>
<tr>
<td>Irradiance (W/m²/nm @ 340 nm)</td>
<td>0.75</td>
<td>0.35</td>
</tr>
<tr>
<td>Black panel (°C)</td>
<td>70</td>
<td>63</td>
</tr>
<tr>
<td>Temp of Clear PC (°C)</td>
<td>55</td>
<td>42</td>
</tr>
<tr>
<td>Cycle 2</td>
<td>Light and Wet</td>
<td>Light and Wet</td>
</tr>
<tr>
<td>Time (min)</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Irradiance (W/m²/nm)</td>
<td>0.75</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Xenon Arc boro/boro similar spectrum to Sun

![Graph showing irradiance vs. wavelength for different cycles and conditions.](chart.png)
Weathering Performance Comparison of Coatings

Exposure in ASTM G155 Cycle 1 Modified
Translated to years in Florida

Exposure at Sample Failure
(years in Florida equivalent)

Exatec® Plasma Coating increases the lifetime of the coated Lexan® Polycarbonate.
Adhesion testing – Cross cut test

**References:** ASTM D3359, ISO 2409

- Adhesion of coating films to substrates by applying and removing pressure-sensitive tape over cuts made in the film.
- Adhesion retention of 99% or better is acceptable after tape peel.
Open Discussion

Testing specifications should reflect real world performance of a windscreen

- Falling sand is a test that make sense to evaluate for windscreen application

- Wiper test is not a standardized test but can provide good correlation with real life

Polycarbonate performance should be in alignment with acceptable expectations
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