QUALITY CONTROLS OF POST-CONSUMER RECYCLED CARPET-BASED RESINS FOR THE AUTOMOTIVE INDUSTRY
Agenda

- Post-Consumer Recycled (PCR) Carpet
- PCR Carpet Recycling Standard (Dry) Process
- PCR Carpet Recycling Centrifugal Separation Process
- PCR Carpet Recycling Extrusion Process
Post-Consumer Recycled (PCR) Carpet
Post-Consumer Carpet Construction

<table>
<thead>
<tr>
<th>Carpet as a Raw Material</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component</strong></td>
</tr>
<tr>
<td>Face Fiber/Tuft*</td>
</tr>
<tr>
<td>Polypropylene</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
</tr>
<tr>
<td>Latex</td>
</tr>
</tbody>
</table>

* Face fiber composition includes Polyamide 6, Polyamide 6/6, polypropylene, polyester, wool, cotton, and acrylic
# Post-Consumer Carpet Purification

## US Carpet Composition

<table>
<thead>
<tr>
<th>Face Fiber (%)</th>
<th>Polypropylene (%)</th>
<th>Calcium Carbonate (%)</th>
<th>Latex (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 - 55</td>
<td>10 - 20</td>
<td>25 - 35</td>
<td>3 - 7</td>
</tr>
</tbody>
</table>

## Dry Standard Process

<table>
<thead>
<tr>
<th>Face Fiber (%)</th>
<th>Polypropylene (%)</th>
<th>Calcium Carbonate (%)</th>
<th>Latex (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>73 - 83</td>
<td>11 - 21</td>
<td>3 - 7</td>
<td>0 - 2</td>
</tr>
</tbody>
</table>

## Centrifuge Process

<table>
<thead>
<tr>
<th>Face Fiber (%)</th>
<th>Polypropylene (%)</th>
<th>Calcium Carbonate (%)</th>
<th>Latex (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>83 - 93</td>
<td>4 - 8</td>
<td>3 - 7</td>
<td>0 - 2</td>
</tr>
</tbody>
</table>

## Carpet Types

<table>
<thead>
<tr>
<th>Carpet Types</th>
<th>Styles</th>
<th>Pros</th>
<th>Cons</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Pile (tufts form loops)</td>
<td>Level Loop</td>
<td>Wears well since tips of fabric not exposed.</td>
<td>May be difficult to conceal seams.</td>
<td>High-traffic areas. Berbers and other casual styles.</td>
</tr>
<tr>
<td></td>
<td>Multi-Level Loop</td>
<td>Wears well. Texture helps hide wear, dirt.</td>
<td>May be difficult to conceal seams.</td>
<td>High-traffic areas. Berbers and other casual styles.</td>
</tr>
<tr>
<td></td>
<td>Saxony</td>
<td>Smooth, dense surface. Twisted fiber adds resilience, hides footprints.</td>
<td>Less durable than loop piles.</td>
<td>Moderate traffic areas. Less formal.</td>
</tr>
<tr>
<td></td>
<td>Frieze</td>
<td>Textured with highly twisted tufts adds resilience, hides footprints.</td>
<td>Curly, textured surface less smooth, plush.</td>
<td>High-traffic areas. Informal settings.</td>
</tr>
<tr>
<td>Cut-Loop (combines cut and uncut tufts)</td>
<td>Cut-Loop</td>
<td>Islands of high cut loops and low uncut tufts create sculpted pattern that helps hide wear and dirt.</td>
<td>Uneven surface, less plush than cut piles.</td>
<td>Family rooms, stairways, other high-traffic areas. Informal settings.</td>
</tr>
</tbody>
</table>
Life of carpet fiber

1. Polymer for carpet yarn
   - High molecular weight
   - Low viscosity

2. Spun fiber yarn
   - Highly ordered and oriented
   - Low viscosity

Degradation
1. Thermo-Oxidative degradation
2. Photodegradation
3. Hydrolytic degradation
4. Biodegradation
   ➔ Molecular scission

4. DRY Separation
   - Molecular scission

5. WET Separation
   - Molecular scission

6. Compounded “ECOLON”
   - B.I.C Flow
   - B.I.C Cooling

7. Injection molded into Auto parts

Hydrolytic
   - Molecular scission

Wellman Advanced Materials
Post-Consumer Reclamation Process

- Post Consumer Carpet Storage
- Sortation
  - ID OK
  - ID Not OK
    - Reject Carpet
- Standard Line Dry Ash Removal Process
  - PCR Fuff Baled off of Standard Line
  - Sampling for DSC and Ash Testing
    - Test Results OK
    - Test Results not OK
      - Reprocessing
- PCR Fluff Storage
- Test Results not OK
  - Reprocessing
- Fluff Room for Blending and Feeding to Raw Material Extruder
- Transfer to Raw Material Extruder
  - Blending and Drying prior to Extruder
- Extrusion and Pelletization on Raw Material Extruder
  - Classification, Pellets run through bank of Rare Earth Magnets and Metal Detection
  - Test Results not OK
    - Reprocessing
- Engineering Resins for Compounding into Finished Product
  - Analytical and Physical Property Testing
  - Test Results OK
    - Test Results not OK
      - Reprocessing
- Two-Stage Coarse and Fine Grind Granulation
  - Densification/Condux Process
    - PP By-Product Tested for purity
      - Test Results OK
      - Test Results not OK
        - Reprocessing
      - Nylon/Polypropylene Separation
        - Centrifuge Process - PCR
          - PCR Bales input to Centrifuge Process at Sort Line #1
            - Bales Staged for Centrifuge Process
              - Nylon and Polypropylene Separated in Centrifuge Process
                - Polypropylene
                  - PP By-Product Tested for purity
                    - Test Results OK
                    - Test Results not OK
                      - Reprocessing
                      - Nylon
                        - Blending and Drying
                          - Nylon and Polypropylene Separated in Centrifuge Process
                            - Densification/Condux Process
                              - Test Results not OK
                                - Blending and Drying
                                  - Extragulation/Condux Process
                                    - PP By-Product Tested for purity
                                      - Test Results OK
                                      - Test Results not OK
                                        - Reprocessing

Post-Consumer Carpet Quality Checks and Control

• The challenges of producing high quality Engineered Resins using PCR carpet as raw material require adherence to high Quality Standards in order to meet the needs and expectations of our customers.
• While PCR carpet comes in various forms, colors and compositions, in general all carpet is produced from higher grade PA6 and PA66 which is necessary due to the method of producing carpet fibers.
• Strict adherence to Quality Standards, Testing and Blending through-out the product realization process allows Wellman to control and maximize the quality of the raw materials that are used to produce high quality Engineering Resins.
PCR Carpet Recycling Standard (Dry) Process
Post-Consumer Carpet Quality Checks and Control

Collected Whole Carpet – Incoming Raw Material Inspection

NIR Identification of Face Fiber for determination of composition
Post-Consumer Carpet Quality Checks and Control

Whole Baled Carpet opened to remove any loose debris (Aluminum tack strips and wood) prior to introduction to the dry Standard ash reduction line.

Fiber Fluff baled off the Standard Line – 10 bale composite (~6000-lb) samples taken while bales are produced and homogenized for ash and DSC testing to determine Polyamide purity.
Post-Consumer Carpet Quality Checks and Control

Fluff bales off of Standard Line plastic wrapped to prevent contamination.

Fluff Bales are stored in the Building 12 warehouse until analytical testing is complete and sort line staging's are prepared for the centrifugal separation of Polypropylene from Polyamide.
PCR Carpet Recycling
Centrifugal Separation Process
Post-Consumer Carpet Quality Checks and Control

- The Standard Line reduces the ash content of the PCR. It also frees the Polypropylene backing that is intermingled with PCR Polyamide Fluff to allow separation in the Centrifuge Process.
- PCR Polyamide Fluff is introduced to the Centrifugal separation process through the Sort Line.
- Upon leaving the Sort Line, the Polyamide Fluff goes through a series of size reductions steps to make it suitable for separation of the Polypropylene backing.
- The size reduced Polyamide fluff is the air conveyed to the Centrifugal separation process.
- The Polyamide Fluff is made into a slurry with water, then pumped into the separation process.
- In the separation process, Polyamide PCR is separated from the Polypropylene backing.

Fluff bales are blended in staging’s on the Sort Line to produce the desired ash content and physical properties.
Post-Consumer Carpet Quality Checks and Control

• The Polypropylene by-product is tested daily by the Building 12 Quality Lab to ensure the purity of the by-product and low yield loss of the Polyamide PCR.

Tests that are performed daily on the by-product
• HCl acid extraction and ash test is performed to determine the composition and to verify purity of the by-product stream.

• Polypropylene by-product is then densified into condux that is used to make high quality Engineered Polypropylene Resins.
Post-Consumer Carpet Quality Checks and Control

Polyamide PCR fiber is separated from the Polypropylene backing in a Patented Centrifugal Separation process. Purity of the recycled PCR is unparalleled with 30 years of experience in Carpet Recycling.

After separation, the Polyamide PCR is blended and dried prior to being air conveyed to a Fluff Room for storage and additional blending in preparation for extrusion.
PCR Carpet Recycling Extrusion Process
Post-Consumer Carpet Quality Checks and Control

A Fluff Room is a specially designed silo for storage and blending of large quantities of Polyamide PCR fiber.

- The Fluff Room is critical for blending and homogenization of Polyamide PCR.
- Provides lot to lot consistency of the raw material and ensures the same for Engineered resins produced form the PCR Polyamide.
- A rotating auger at the bottom of the Fluff Room pulls the PCR fiber to the center where it is discharged and air conveyed to the extrusion process.
• PCR Polyamide fiber is metered and fed to a single-screw raw material extruder using a force feed hopper. A vacuum zone on the RME allows de-volatilization of the polymer prior to exit and pellet formation.

• Pellets are then classified to remove fines and long-cuts.
• In the final step of the raw material production process, the pellets are past through banks of rare earth magnets and metal detection.
• Any ferrous or non-ferrous metal detected in the pellets are sent to rejects bin.
Post-Consumer Carpet Quality Checks and Control

The resulting PCR Polyamide raw material is now ready to use as feedstock for compounding into high quality Engineered Resins.

Final Raw Material Quality Checks

- Pellets produced undergo ash and moisture testing on each box produced.
- Pellets from each Lot are ground for DSC testing and composition analysis. Any off-spec material is placed on hold for reprocessing.
- Additional Lot testing includes Relative Viscosity (RV) and Physical Property testing which includes:
  - Tensile Strength and Modulus
  - Elongation
  - Density
  - Notched Charpy and Izod Impact
  - Flex Modulus and Strength
  - Heat Distortion Temperature
  - Shrinkage in Flow and Trans direction