Performance of Conformable Ablators in Aero thermal Environments
J. Thornton1, W. Fan1, K. Skokov3, M. Stackpool1, J. Chavez-Garcia1, D. Kao1, V. Qu4, R. Beck* 1ERC Inc., Moffett Field, CA  *NASA  4Education Associates Program

1. Background
- Thermal blankets protect space vehicles in areas that reach up to 371 °C (700 °F) upon entry into an atmosphere. They are mainly used for their insulative properties and low density, but their flexibility is also very beneficial.
- Conformable ablators have sparked interest due to their potential to withstand relatively high heating rates (=250 W/cm²) while having the ability to be molded to the desired shape during processing.
- Conformable ablators consist of a felt base (such as carbon felt) and a resin, which, upon curing, shows good thermal insulative properties at heating rates of 200 W/cm² or higher.
- The density of conformable ablators depends on the density of the felt used and concentration of resin, but is usually in the range of 0.20 g/cm³ to 0.30 g/cm³.
- Conformal heatshields offer several advantages compared to rigid heatshields, including potential lower thermal conductivity, lower thermal stresses, lower risk of failure due to crack growth, and ease of installation.
- Conformal heatshields are probably less expensive, since they can be made in one piece compared to tiles for a rigid heatshield.

2. Conformable Ablator Processing
- Carbon felt is impregnated with a resin and then cured in an oven to form a composite material.
- The resulting composite material is then used in the construction of conformable heatshields.

3. Importance of Morphology in Ablator Systems
Morphology refers to the microstructure of an ablator system and the location of phenolic polymer (or infiltrant) relative to the fiber substrate used.

Example of Poor Morphology
Previous work on rigid ablators has shown that morphology is directly related to thermal efficiency. An increase of phenolic polymer will increase the thermal efficiency of phenolic ablators, as can be seen in the image on the right.

Example of Good Morphology
The high density and phenolic resin in the right ablative increases the heat transfer and increases the thermal efficiency. The high density and phenolic resin were obtained using a Netzsch Laser Flash Analyzer.

4. Focus of This Work
1. Test several conformable ablators in the same aero thermodynamic environment and evaluate the performance.
2. Down select to two conformable ablators that will be further tested and evaluated to compare their performance in an aero thermodynamic environment and their thermal and mechanical properties.
3. Down select to one conformable ablator that will be advanced to TRL 5 or 6 by end of 2013.

5. Conformable Ablators Investigated
Two carbon felts, made by FMI (Fiber Materials, Inc.) and Morgan AMET, were used to make the conformable ablators in the tables on the right. Morgan’s felt was flat and had no wrinkles, while FMI’s carbon felt was not completely flat and had wrinkles on one side of the felt.

6. Mechanical Properties of Conformable Ablators
Stress Strain Curves of Conformable Ablators with Phenolic Resin

7. Arc Jet Data on Conformables
Results from 20 second exposure

<table>
<thead>
<tr>
<th>Sample Description</th>
<th>Heat Flux (W/cm²)</th>
<th>Pressure (kPa)</th>
<th>Temperature (K)</th>
<th>Energy Absorbed (J/cm²)</th>
<th>Shear at 0.10 (MPa)</th>
<th>Maximum Shear (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMI felt with standard phenolic loading</td>
<td>540</td>
<td>4.6</td>
<td>30</td>
<td>7.0</td>
<td>80.7</td>
<td>109</td>
</tr>
<tr>
<td>Morgan felt with standard phenolic loading</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>8.2</td>
<td>54.9</td>
<td>543</td>
</tr>
<tr>
<td>Morgan felt with high phenolic loading</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>5.8</td>
<td>42.5</td>
<td>946</td>
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<tr>
<td>FMI felt with standard phenolic loading plus additive</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>5.0</td>
<td>89.8</td>
<td>160</td>
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<tr>
<td>FMI felt with silicon</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>6.6</td>
<td>84.3</td>
<td>440</td>
</tr>
<tr>
<td>Morgan felt with silicon</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>6.0</td>
<td>120</td>
<td>105</td>
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Results from 30 second exposure

<table>
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<th>Sample Description</th>
<th>Heat Flux (W/cm²)</th>
<th>Pressure (kPa)</th>
<th>Temperature (K)</th>
<th>Energy Absorbed (J/cm²)</th>
<th>Shear at 0.10 (MPa)</th>
<th>Maximum Shear (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMI felt with standard phenolic loading</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>9.4</td>
<td>100</td>
<td>87</td>
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<td>Morgan felt with standard phenolic loading</td>
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<td>6.4</td>
<td>20</td>
<td>8.9</td>
<td>51</td>
<td>730</td>
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<tr>
<td>FMI felt with standard phenolic loading plus additive</td>
<td>540</td>
<td>6.4</td>
<td>20</td>
<td>7.2</td>
<td>100</td>
<td>94.2</td>
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<tr>
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<td>6.4</td>
<td>20</td>
<td>15.5</td>
<td>77</td>
<td>224.3</td>
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</tbody>
</table>

8. Future Work
Samples C and F have been made in a geometry that conforms to part of a cone and be exposed to 250 W/m² at NASA Ames Research Center for further testing.

9. Summary
• Although the commercial felt and additive (sample D) had the best mechanical properties and the least recession, it was not selected for further testing because of concerns with manufacturing large pieces.
• The high phenolic loading in the Morgan felt (sample C) was responsible for the low recession and low change in the backface temperature.

Acknowledgment
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