Conformal Ablative Thermal Protection Systems (CA-TPS) for Venus and Saturn Backshells

1: Background

CA-TPS: The Problem – The Solution

The Problem

- NASA requires TPS ablative advances for Venus and Saturn missions.
- Current TPS concepts require complicated manufacturing and assembly processes.
- SOA materials require complicated installation techniques and high labor costs.
- Limited number of certified TPS materials available.
- PICAs require extensive test facilities, large discount, and complicated NDE.

The Solution

- Developed high-strain rubber TPS capable of ~200 W/cm².
- Successfully tested at ~400 W/cm².
- Utilized rubber materials for a rigid reinforcement and machine-structured shape.
- New material is used for more efficient and lower manufacturing costs.

7: Key Performance Parameters

<table>
<thead>
<tr>
<th>Conformal Ablative Blank Performance Parameters</th>
<th>Category Offsets</th>
<th>State-of-the-Art Values</th>
<th>TRL 5 Performance Goal</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPP-C1</td>
<td></td>
<td>Non-representative pressure gradients and other dimensional errors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KPP-C2</td>
<td></td>
<td>Rubber materials need to be flexible, resistant to mechanical damage, and to undergo structural changes properly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KPP-C3</td>
<td></td>
<td>Manufacturing feasibility.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KPP-C4</td>
<td></td>
<td>Risk to flight safety and reliability must also be reduced to a minimum.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3: Conformal Ablator TPS Development

- New TPS rubber testing approach.
- Heritage sphere test configurations (caved copper wedges) resulted in non-representative pressure gradients and other dimensional errors.
- Flow blurt spherical (smaller) design results in flow-like gradients and similar field.
- Objectives of the test:
  - Demonstrate manufacturability of conformable skins on a sphere structure at MSK-type and COTS ULCC conditions or beyond.
  - Demonstrate advanced instrumented (conformable) and measure-in-situ temperature data for the development of a material response model.
  - Gather recession and back-face temperature data on conformable ablator at representative heating and structural environments for verification and validation of mission requirements.
  - Investigate different skin designs.
  - Compare materials on a single and multiple.

5: Demonstration of Scale-Up of C-PICA

- Part-scale-up – Design and build a prototype demonstration unit (PDU).
- Objective: to demonstrate scale-up of manufacturing for different flight systems, handling, machining, and assembly of large parts.
- Metal molds designed and fabricated.
- First, thick test part produced for evaluation.
- Changes recommended and second part underway.

6: Conformal Ablator Mission Infusion – Small Probe Development with Terminal Velocity Aerospace

- Small probe vehicle designed for break-up evaluation.
- tasked responsible for probe design.
- Ames responsible for TPS selection, sizing, manufacturing, instrumentation, and installation for initial arc jet models and test flight vehicles.
- Ames hardware.
- Baseline TPS bounded to different structures:
  - Boeing Inflatable Cylindrical Ablator (ICAOA)
  - Inlet instrumented model.
  - Inflatable TPS bounded to different structures.
  - C-PICA.
  - Other instrumented model.
- Remaining hardware is TPS responsibility.
- Design for testing at 200 W/cm² on the nose, 200 W/cm² on the back.
- Flight manifest: Flight Mission: from Station 1 to Y10

Progress to date:
- Vehicle and arc jet test article configuration is completed.
- Test article is being processed and measured.
- TPS parts designed for arc jet testing.
- Processing and manufacturing.
- Segments for arc jet test articles processed, instrumented, assembled, and tested.
- Processing, and assembled.
- Processing of flight materials underway.

7: Work to Go: Advancing C-PICA from TRL5 to TRL6 for New Frontiers Venus Backshell Applications

- Why C-PICA for backshells?
  - Perforate - a material called LTV no longer made.
  - Baseline testing should be C-TPS.
  - C-PICA is a very efficient, high-stretch, stiffer elastomer that integrates and replaces the backshell.
  - C-PICA is a lower cost, higher-strain material that integrates with the current backshell process.

C-PICA has much better performance in flexure testing than PICAs

- Fat Scale-up successful for thick C-PICA.
- * Rayon Felt yields C-PICA.
- State of the art for carbon felt - 1.6 mm. thick, density 0.6-1.0 g/cm³ resulting in >6.5 finned parts.
- Design for thicker and higher-density felted with a felt texture to make 2.4 rayon-based with 65000, which will be 3.35/0.985 to 3.0.

8: Acknowledgements

- This work is funded by NASA’s Space Technology Development Program, the Science Technology Mission Directorate.
- Jet engine design and manufacturing instrumentation and assembly performed by NASA Ames TSS Branch.
- Arc jet testing performed by NASA Ames TSS Branch.
- Team effort developed by American Frey and Fiber Company (AFFCO) and collaborated by Fiber Materials Inc.
- Sub panel processed by the Ablation Laboratory at Applied Research Associates, Inc.