ABLATIVE CARBONACEOUS THERMAL PROTECTION SYSTEMS (TPS) MATERIALS FOR SPACE APPLICATIONS

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Introduction

In this paper, results of screening tests of carbon phenolic composites for the forebody heatshield of the Mars Sample Return (MSR) Earth Entry Vehicle (EEV) are presented. Due to high reliability requirements of EEV, those thermal protection materials that have been used successfully in the past were considered only (such as the forebody heat shield on the Pioneer Venus and Galileo entry probes).

Thermal Protection Materials for Mars Sample Return Mission

NASA Ames Research Center was able to acquire a small quantity of heritage rayon based carbon fabric CCA-3 (1641B) used in the above missions. Fully dense chopped-molded (CM) and tape-wrapped (TW) carbon phenolic composites were fabricated using this fabric in accordance with the original composite processing specifications used for the Galileo probe heatshield. In addition, similar composites were fabricated using carbon fabric derived from Lyocell, a synthetic rayon replacement. Two phenolic resins, SC1008 and 91LD, were used to make composites. In total, six different carbon phenolic composites were made and are listed in Table 1. The thickness of all test specimens was 1.27 cm.

Table 1. Summary of tested carbon phenolic thermal protection materials.

	Carbon Fabric/Phenolic Resin	Density, g/cm^3
Tape-Wrapped Carbon Phenolic (TWCP) 30 °-angle ply	CCA-3 (1641B)/91LD*	1.47
	CCA-3 (1641B)/SC1008	1.47
	Lyocell/SC1008	1.33
Chopped-Molded Carbon Phenolic (CMCP)	CCA-3 (1641B)/91LD*	1.45
	CCA-3 (1641B)/SC1008	1.42
	Lyocell/SC1008	1.44

* Galileo pedigree fabric and resin system

The materials discussed in this paper were tested in the plasma arc jet flow at the Interaction Heating Facility (IHF) at NASA Ames Research Center. The testing was done in a mixture of approximately 10 % argon and 90 % air at two conditions: (1) a heat flux of 1500 W/cm^2 for 7 sec.; (2) a heat flux of 750 W/cm^2 for 13 sec. These conditions represent the maximum and half of the maximum of the predicted heat flux during flight, and approximately the same total heat load for both conditions and the flight.

Results

During the arc jet test, the surface temperature and the backface temperature of the specimens were monitored continuously. After the test, other measurements (such as surface recession and weight loss) and materials characterization were performed, and a comparison of actual backface temperature and recession data to the modeling predictions was performed. A sample of temperature data is presented below.

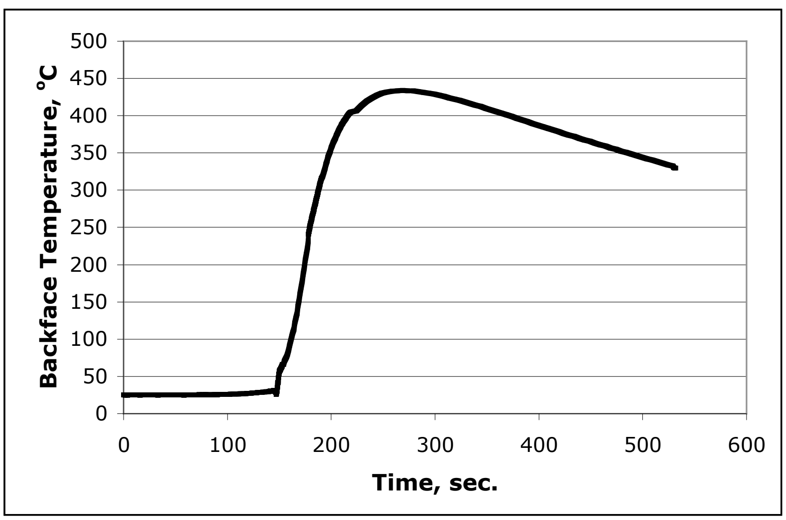

Figure 1. Example of backface temperature response during the arc jet test of a Lyocell/SC1008 TWCP composite at 1500 W/cm^2 for 7 sec.

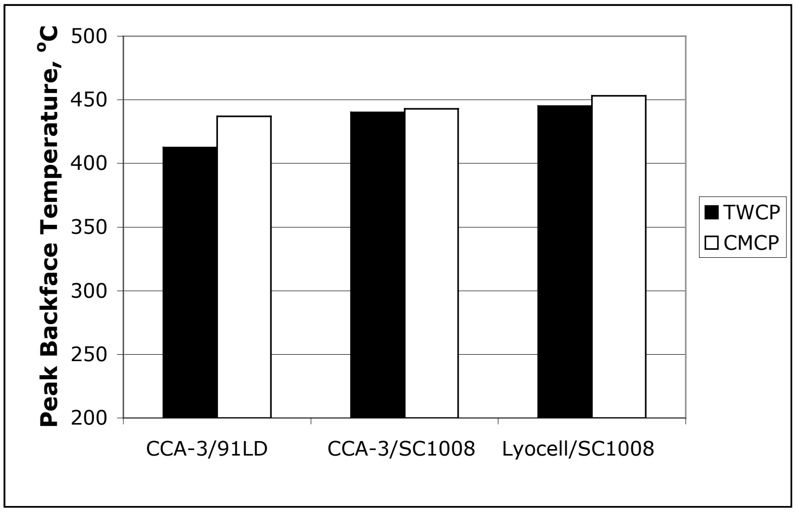

Figure 2. Summary of peak backface temperatures for different carbon phenolic composites tested at 1500 W/cm^2 for 7 sec.

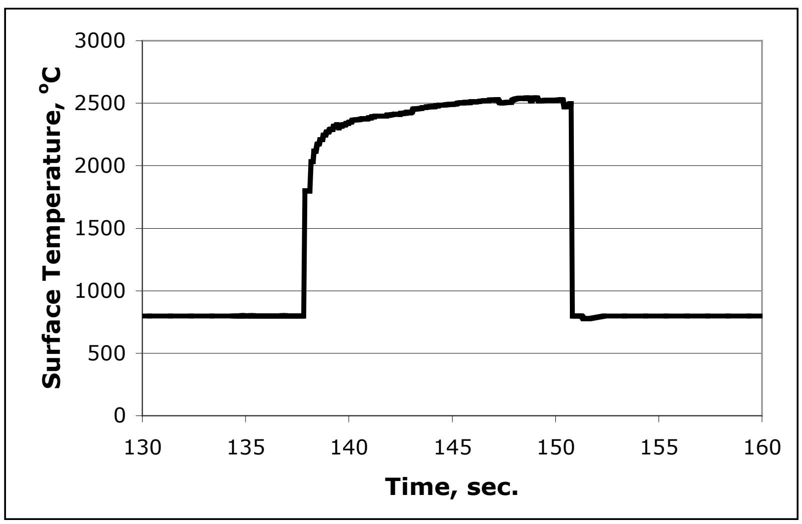

Figure 3. Example of surface temperature rise during the arc jet test of a CCA-3/SC1008 TWCP composite tested at 750 W/cm^2 for 13 sec.

Conclusions

The test series was successful and demonstrated that both TWCP and CMCP and all the variants, including the Galileo heritage carbon phenolic and Lyocell-based carbon phenolic, performed adequately at both heat fluxes and showed suitability for use as the forebody TPS for MSR EEV. This conclusion was done on the basis of analysis of material integrity after the test, as well as on the comparison of actual temperature and surface recession values to the modeling predictions.