Thermal Management Coating

Thermal Management Coating As Thermal Protection System for Space Transportation System

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Thermal Management Coating

Background

- Thermal Protection System (TPS) loss from ET or SRB during Shuttle flight and related Orbiter tile damage necessitates development of a non-ablative thermal management coating
- Coating design requirements
  - Moisture resistance
  - CTE compatibility with aluminum
  - High temperature performance (Aerothermal test)
  - Maintain low temperature of the aluminum substrate during Shuttle flight
  - Minimum or no structural weight increase

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Coating Study

- Coating formulation
  - High strain to failure binder
    - Flexible liquid epoxy resin
      - Low viscosity
      - Low moisture absorption
      - High temperature stability
  - Heat absorbing microcapsules as additive
      - Micro-encapsulated phase-change materials (15-100 micro)
      - Absorb or release tremendous amounts of heat without corresponding change in temperature

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Coating Study (Cont.)

- Aerothermal Testing (MSFC Hot Gas Facility)
- Thermal Testing
  - TGA, DSC
  - Thermal Conductivity
  - Specific Heat
- Mechanical Testing
  - Strain Compatibility
  - Flatwise Tensile
  - Flatwise Tensile After Aerothermal Testing

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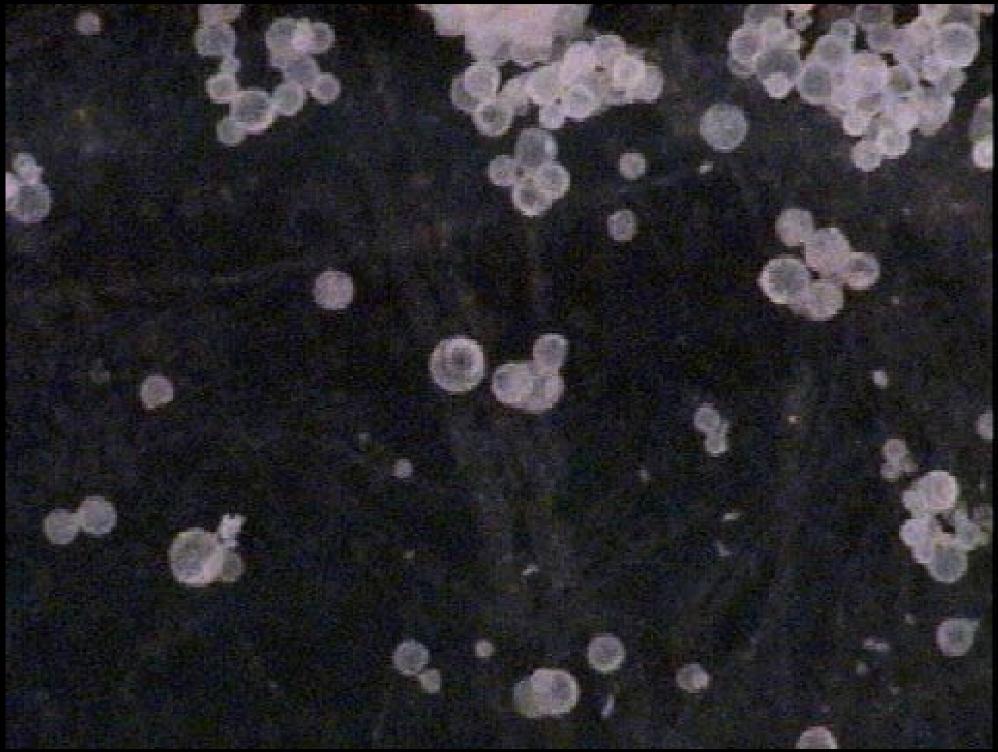

Microcapsules 20X

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Aerothermal Testing

- Test Environment
  - SRB Nose Cap Design Environment (BP 1003)
    - Recovery Enthalpy 600 BTU/lb_m
    - Peak Heating Rate 9.4 BTU/ft^2-sec
- Evaluation Parameters
  - Substrate Temperature
  - Thickness Change
  - Variables
    - Coating thickness
    - Loading percentage of phase change material
    - Different latent heat microcapsules
    - Preconditioning of test specimens
      - Humidity chamber
      - Salt Fog
      - Lightning strike
      - Impact simulation
    - Reusability

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Aerothermal Testing (Cont.)

- Evaluation Parameters
  - Substrate Temperature
  - Thickness Change
- Variables
  - Coating Thickness
    - Minimum Thickness – 25 mils
    - Maximum Thickness –105 mils
  - Loading Percentage
    - Minimum Loading – 33%
    - Maximum Loading – 70%
  - Latent Heat Microcapsules
    - PCM111
    - TH122
    - TH175

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Preconditioning Environments

- Humidity Chamber
  - 95% Relative Humidity
  - 100°F
  - 10 Days
- Salt Fog
  - 5% Saline Solution
  - 100°F
  - 2 Days
- Lightning Strike
- Impact
  - Loads Simulating Ice Impact (14 to 48 ft/lbs)
- Reusability
  - Panel Exposed to SRB Design Environment BP 1003 5 Times

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Test Observations

- Moisture Absorption
  - Slight weight gain (<4 gms after 10 days in humidity chamber)
- Lightning Strike
  - Good electrical insulator
- Impact Testing
  - Partial compaction recovery
- Substrate Temperature
  - Mainly dependent on coating thickness
  - Loading percentage of secondary importance
  - Not affected by preconditioning
  - Reuse causes little decrease in performance
- Thickness Change
  - Minimal recession when surface temperature <600°F
  - Very low recession rate at heating rates <10 BTU/ft^2-sec

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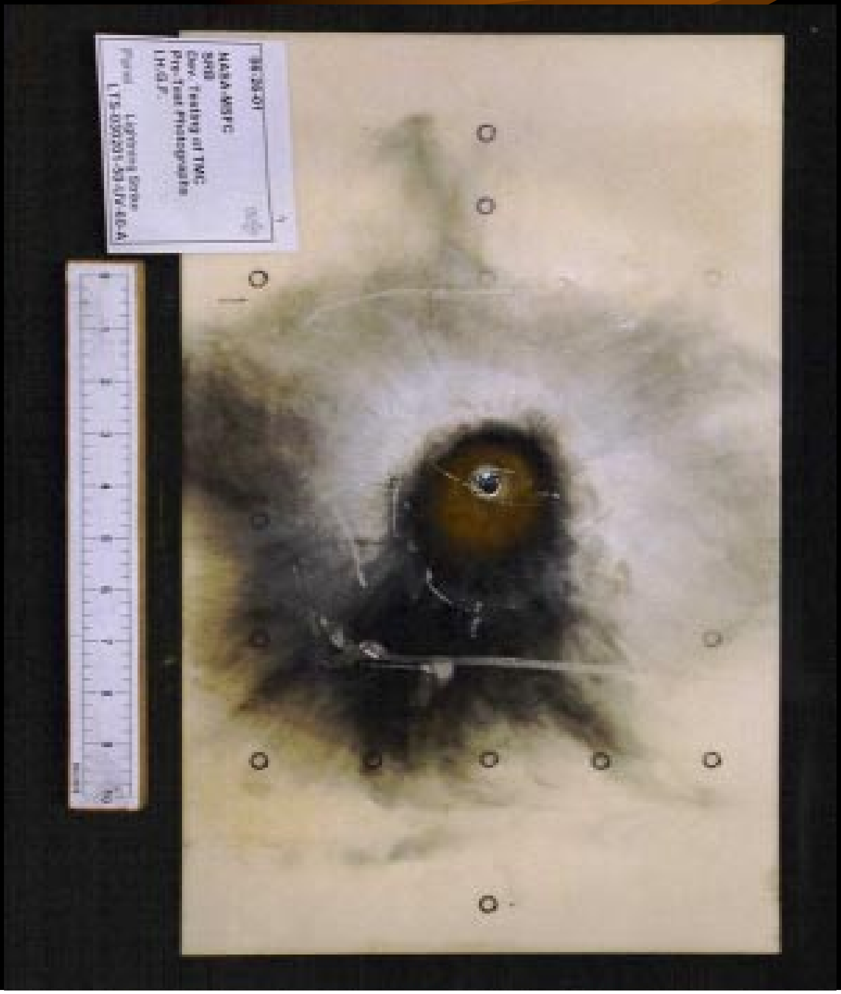
Lightning Strike Test Panel



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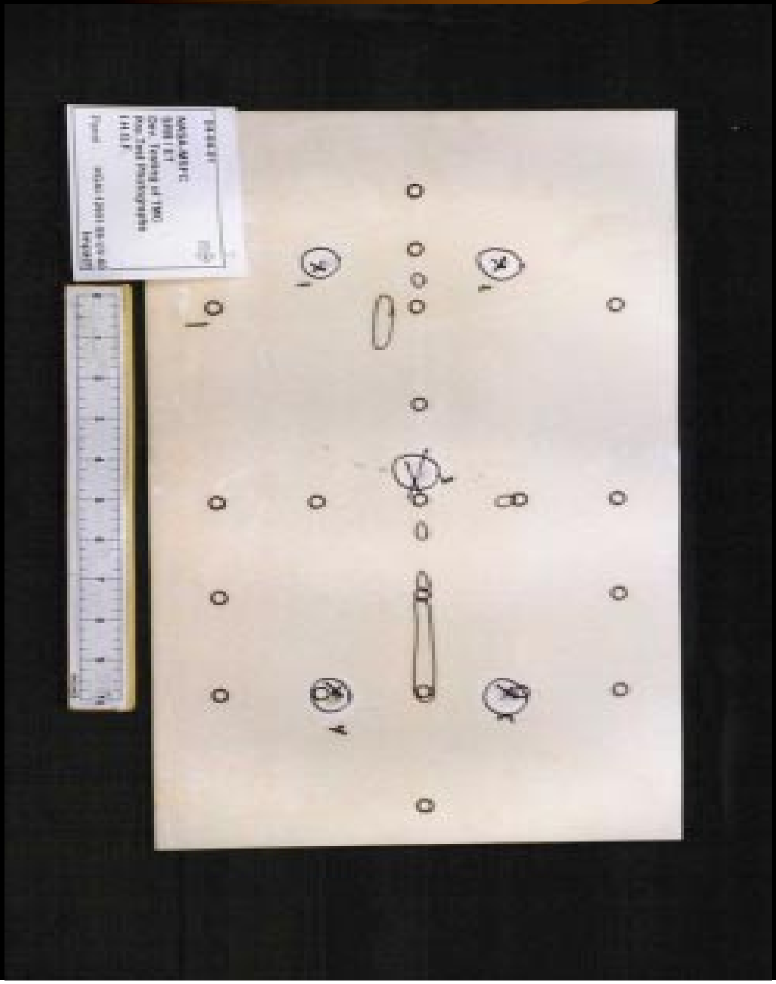
Test Panel After Impact Testing



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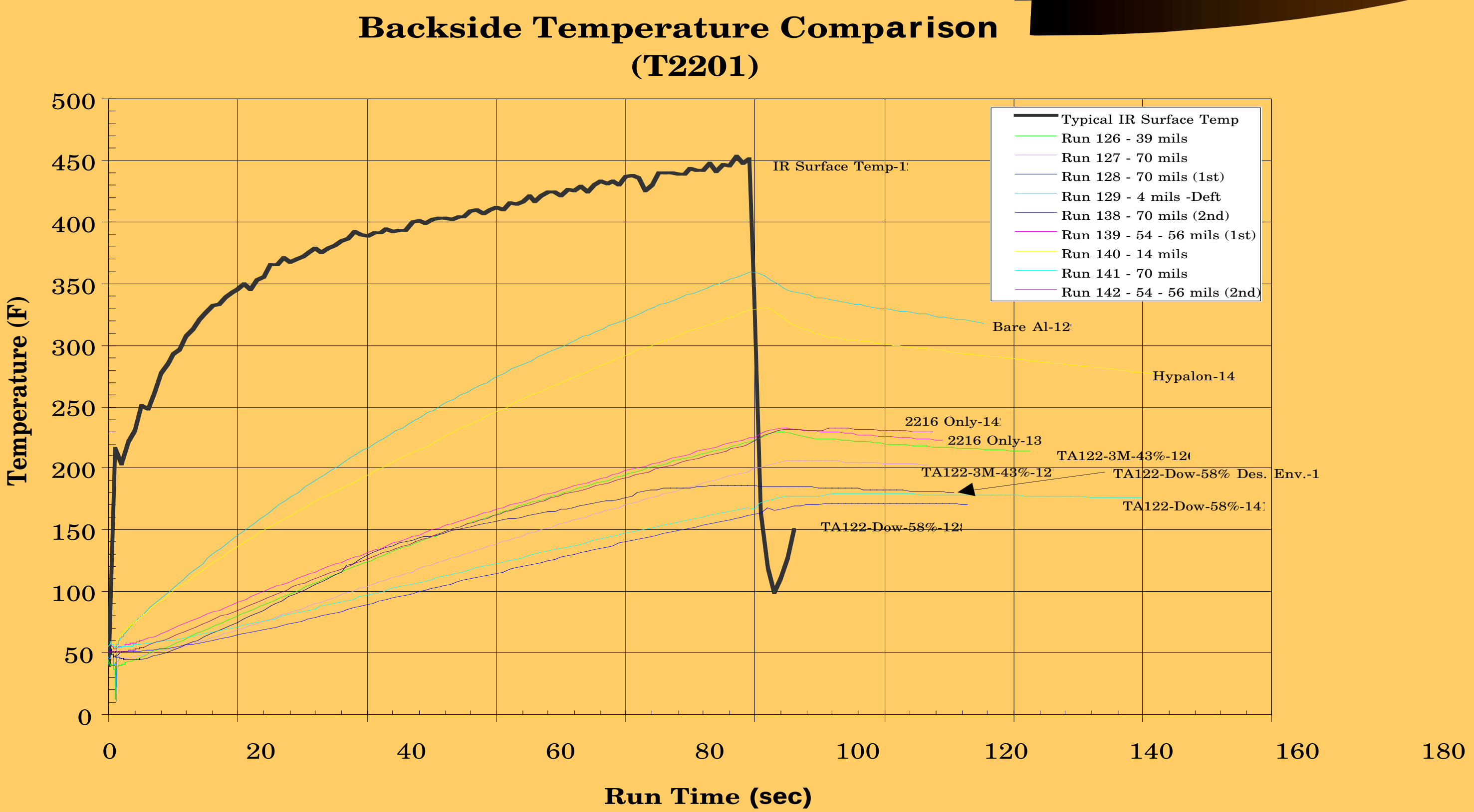

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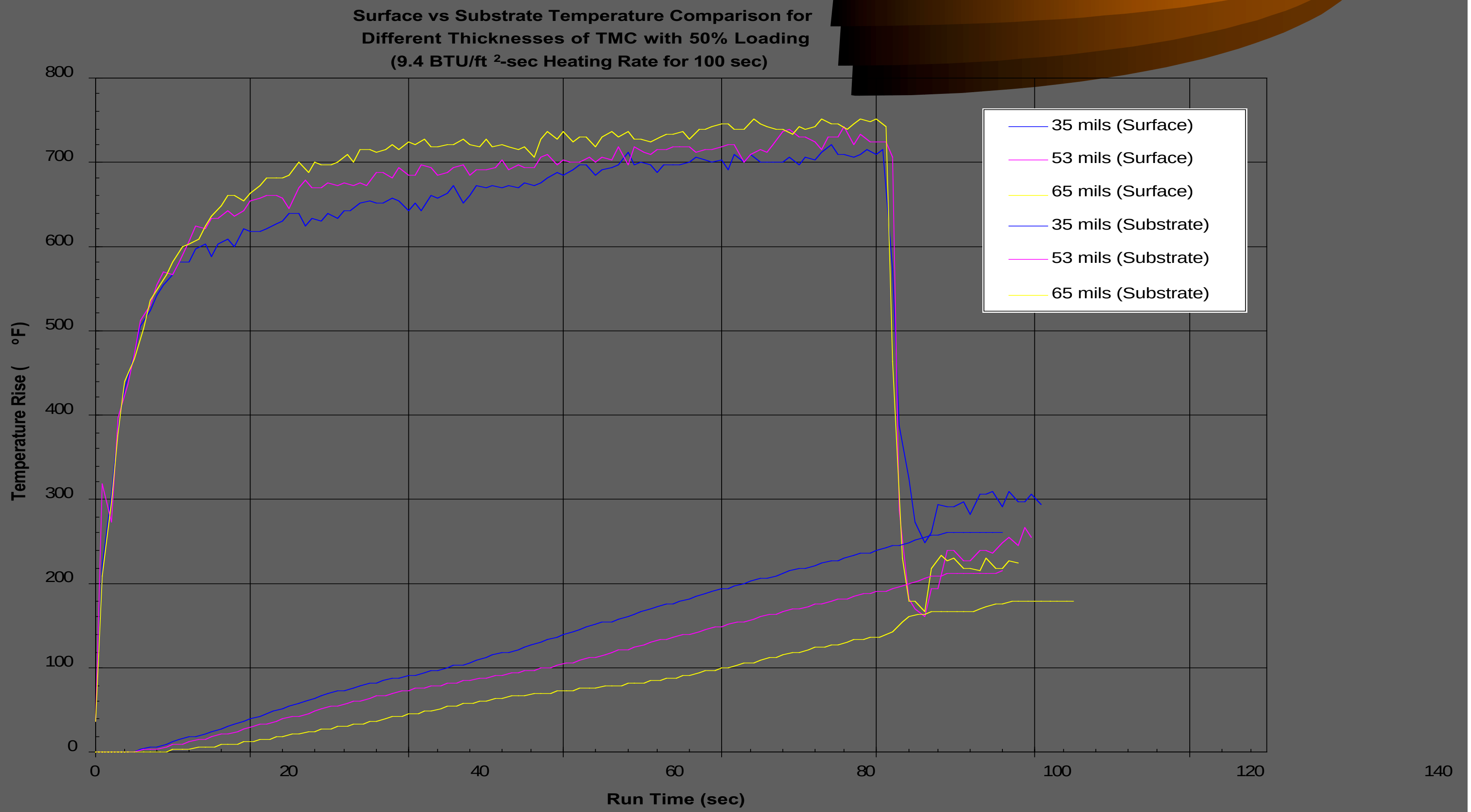

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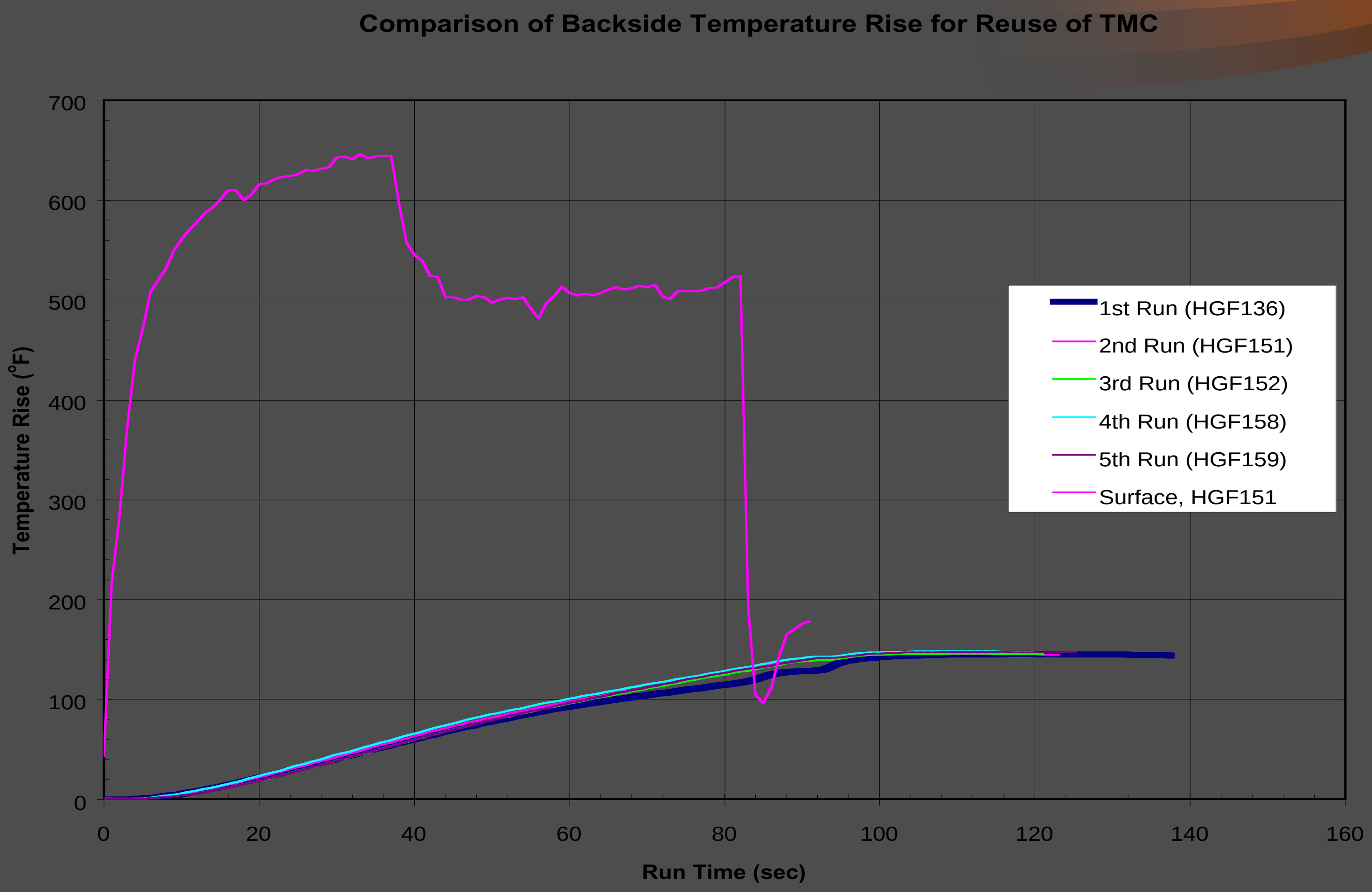

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Thermal Testing

- Charring Temperature of Resin (TGA)
  - 612 °F in air
  - 615 °F in argon
- DSC Data Generated with Different % Loading
- Thermal Conductivity
  - Epoxy 1.52 (BTU-in/hr-ft_-°F) at 170°F
  - TMC 58% Loading 1.67 (BTU-in/hr-ft_-°F) at 170°F
  - TMC 70% Loading 1.65 (BTU-in/hr-ft_-°F) at 170°F
- Specific Heat
  - Epoxy 0.47 (BTU/lb-°F) at 170°F
  - TMC 58% Loading 1.23 (BTU/lb-°F) at 170°F
  - TMC 70% Loading 1.43 (BTU/lb-°F) at 170°F

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Mechanical Testing

- Strain compatibility tensile testing
  - Coating applied to 6061T6Al
  - 50% and 58% loading in epoxy binder
  - The coating failure strain is same as of 6061T6Al

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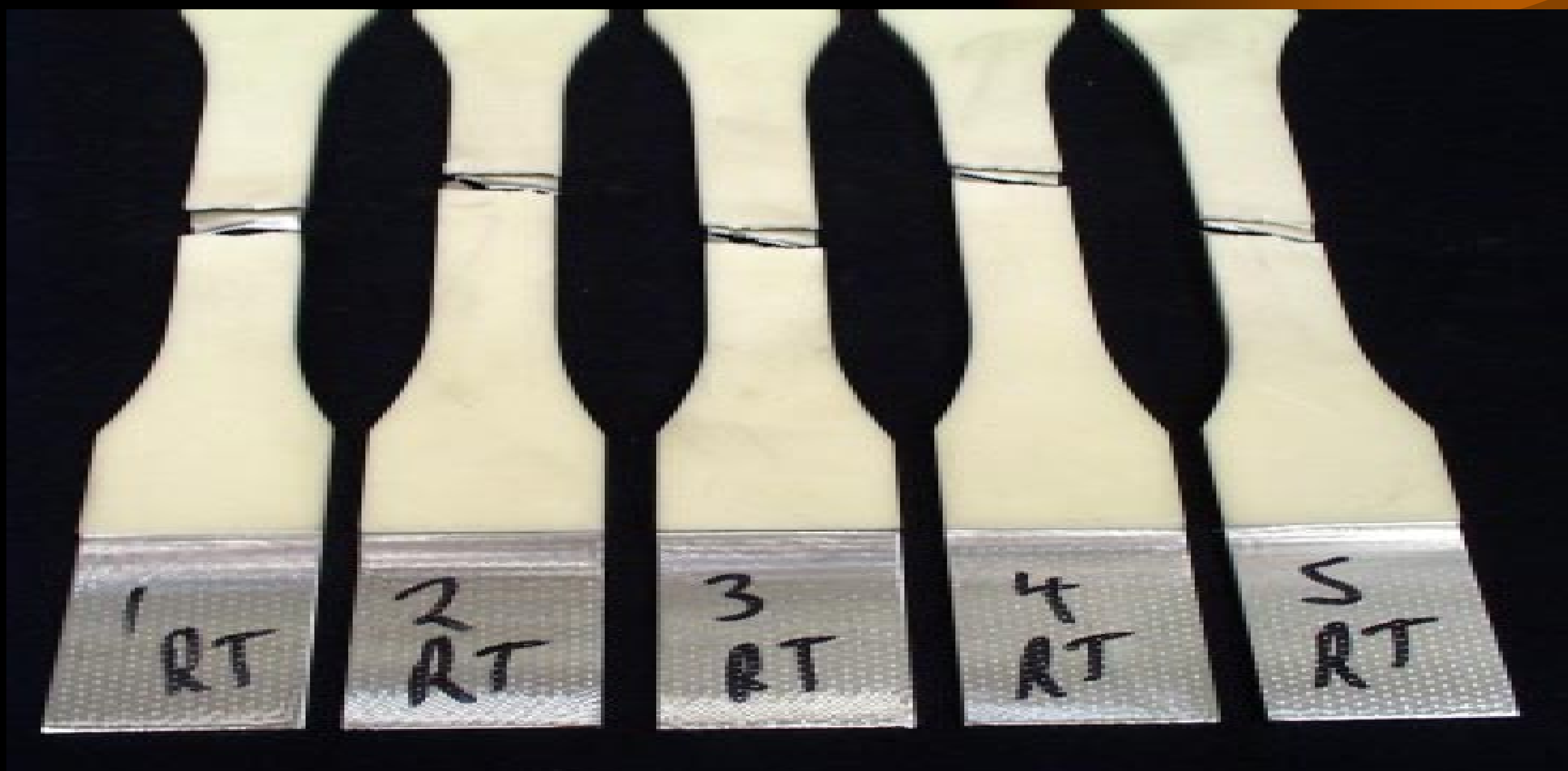

TMCSC-91458UV (58% Loading) Tested at RT

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- Flat-wise Tensile Test Results

50%	Epoxy	60 mils	RT	205.20	Adh
58%	Epoxy	62 mils	RT	244.90	Adh
50%	Epoxy	60 mils	20°F	429.80	Adh
58%	Epoxy	62 mils	20°F	414.40	Adh
50%	Epoxy	60 mils	300°F	9.56	Paint
58%	Epoxy	62 mils	300°F	21.34	Paint
58%	Polyurethane	60 mils	RT	246.00	Adh/Coh
58%	Polyurethane	60 mils	300°F	37.96	Adh

Tensile Coating Film

Filler Loading	Binder	Tensile Strength psi	Tensile Strain (%)	Modulud psi
50%	Epoxy	198.7	26.3	1262.13

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Binder	% Loading	Test Environment	Flatwise Tensile (As-Sprayed/Post-HG (psi)		
			20°F	Ambient	300°F
Epoxy	58	9.4 BFS for 100 sec	414.4/490.3	244.9/285.9	21.3/22.1
Epoxy	50	9.4 BFS for 36 sec 4.8 BFS for 44 sec	429.8/511.5	205.2/244.7	9.6/15.1
Epoxy	58	9.4 BFS for 36 sec 4.8 BFS for 44 sec	414.4/548.7	244.9/289.4	21.3/23.4

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Conclusions

- Potential Replacement for Current SRB TPS Material and Other Launch Vehicles
- Exhibits Potential for Reusability
- Absorbs Little Moisture
- Good Electrical Insulator
- Further Investigation in Progress