Development of Advanced Lightweight Polymeric Foam Thermal Protection for Space Launch Vehicles

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INTRODUCTION

Lightweight thermal protective materials are essential for temperature regulation during ascent of space launch vehicles, especially for expendable launch vehicles and cryogenic propellant tanks. Among the lightest thermal protective materials commonly in use is polymeric foam, in the form of pour foam or spray-on foam insulation (SOFI). Foam processing is rapid, can accommodate large-scale or small-scale challenging geometries easily, and can be used in a climate controlled or non-climate-controlled setting. Application systems can be fixed or portable. Usetemperatures of foam range from cryogenic to those that will ablate the material.

SOFI Foam Is Qualified for Space Flight

Spray-On Foam Insulation (SOFI), a closed-cell polyurethane foam, has been Qualified as a manual spray system suitable for use on launch vehicles, propellant tanks, and other applications requiring thermal protection.

Manually sprayed SOFI does not require





EM41 TPS Foam Application

Foam formulation and application method is chosen depending on the required material properties, application location, and processing environment.

- <u>Automatic spraying</u> of foam is performed by EM41 using a 9-axis robot in a fully climate-controlled 30'x30'x85' processing booth at MSFC Building 4765.
- Manual foam spray systems are portable and can be used wherever spraying is needed, including outdoors. Optimal for complex line-of-sight geometries, large to medium scale touch-ups and repair of foam.
- **Pour foam**, applied manually to hardware or test fixturing, is often used for complex geometric closeouts and thermal insulation of hard to insulate areas, non-line-of-sight applications, or for small scale touchups and repair of foam.







substrate heating to obtain appropriate adhesion to meet SLS Core Stage requirements and has a broader environmental processing window than the robotically sprayed foam used on other areas of the SLS Stages.

SOFI can be manually applied at room temperatures and relatively high humidity, allowing greater flexibility in production environments that do not have stringent environmental control capability.

Launch Vehicle Stage Adapter 1 (LVSA1) After SOFI Application, Trimming, and Final Machining.

Qualification Objectives Achieved

- ✓ Demonstrated that manually sprayed SOFI is Qualified for use on SLS.
- Provided material characterization data to anchor material models and analyses, material selection decisions, and risk assessments.
- Supported broadening of MSFC-SPEC-3686 ranges derived from Development work, leading to decreased processing cost and increased ease of material acceptance.

Manual Spray of Curved Barrel Section Analog for Process Determination.

SOFI Applied to Pipes as Thermal Insulation in Support of Cryogen-involved Testing.

Test Specimens and Capability

Examples of testing performed in support of SOFI Qualification and demonstrations of the flexibility of manually sprayed SOFI are shown below.



SOFI Gradient Cryoflex Sample Ramp and Tab



- \checkmark Justified shelf-life extensions for aged foam components, decreasing processing cost.
- Provided an initial assessment of several repair configurations involving various foams and tie-coat material.
- Determined that post-spray aging and environmental exposure of various durations and sequences (following the plan for Core Stage once it leaves MAF) showed no appreciable impact upon material properties.

Testing and Analysis Summary

Extensive testing and characterization was performed on manually sprayed SOFI, consisting of chemical, physical, thermal, and mechanical test techniques.

- Performed 15 chemistry and reactivity tests over 4 lots of material at 3 component material ages; 18 samples, 294 datapoints.
- Performed 26 thermal, mechanical, and physical tests on 4 lots of material sprayed at 3 component material ages and at 5-6 foam spray environmental conditions onto 2 types of substrate; 5,797 samples, 11,330+ datapoints.
- Performed 15 thermal, mechanical, and physical tests on 2-4 lots of material which was post-spray aged using three different schedules on two types of substrate; 1,074 samples, 2,492+ datapoints.



SOFI Flammability Test



SOFI Room Temperature Bond Tension Test

SOFI Applied to Large Diameter Tank with Short Barrel Section



Small Cryostat - Prepared, Sprayed, Machined

All procurement, materials, material applications, machining, and testing were evaluated by NASA Quality Engineering and incorporated Quality Assurance oversight and buy-offs at appropriate steps.

REFERENCES

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SOFI Closed Cell Microstructure, 20X