IMPACT FOAM TESTING FOR MULTI-MISSION EARTH ENTRY VEHICLE APPLICATIONS

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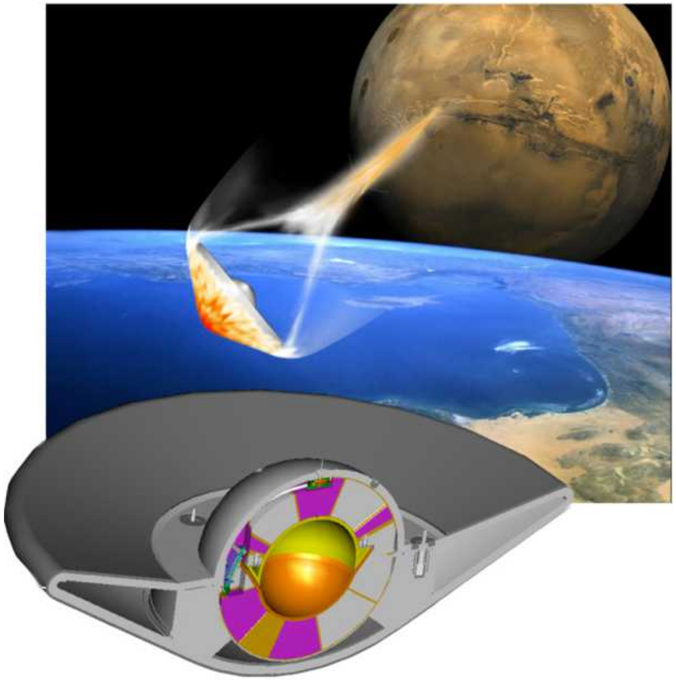
Overview

- **Discuss Multi-Mission Earth Entry Vehicles (MMEEVs)**
- **MMEEV impact and thermal soak analysis**
- **Thermal Conductivity Test**
  - Test objectives
  - Facility
  - Samples
  - Results
- **Summary, Plans**

Overview and Introduction

- **Multi-Mission Earth Entry Vehicles (MMEEVs)**
  - Considered a family or type of vehicle
  - Can be designed to meet specific mission requirements
  - Achieve high reliability through single-stage EDL concept
  - No reaction control systems, parachutes, etc.
  - Perform “free flight” after release from carrier spacecraft
  - NASA is developing the trade space for these vehicles



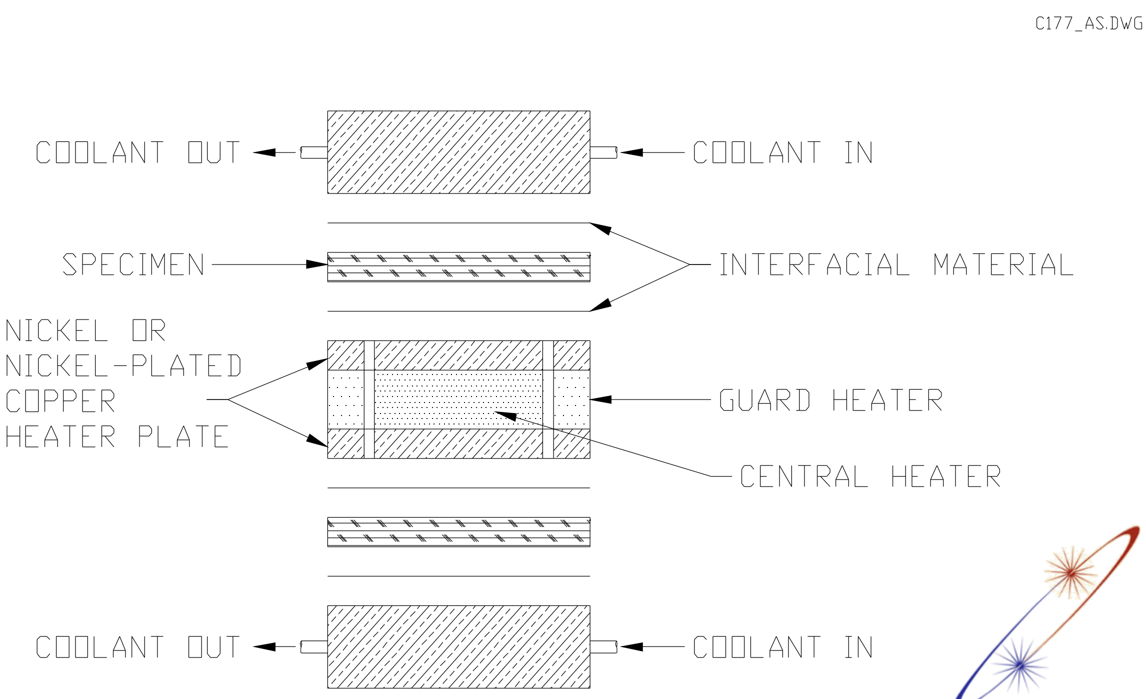
- **Impact foam modeling requirements**
  - Concept of Operations can include extended recovery times
  - During this time heat, stored in the heatshield, can flow into the vehicle and increase payload temperatures (referred to as thermal soak)
  - Thermal soak analysis requires adequate modeling of the vehicle before and after impact
  - Impact foam data for post-impact condition unavailable

IN-SPACE PROPULSION

Test Objectives, Method, Facility

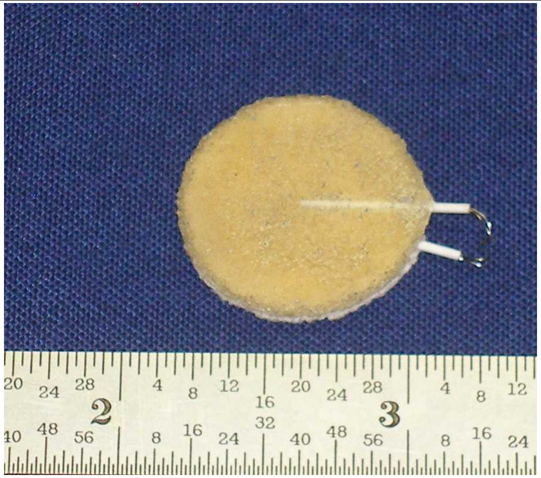
- **Provide data to support MMEEV thermal soak analysis**
  - Define the effect of impact on the foam's thermal conductivity
  - Verify manufacturer's specifications and provide higher-fidelity model data for pre-impact conditions
- **Method**
  - Test series of impact foam samples in Southern Research Institute's (SRI's) 7" Guarded Hot Plate (GHP) test apparatus
  - For both virgin and impacted condition
  - For a range of Rohacell impact foam densities
    - 71-WFHT and 110-XTHT

- **SRIs 7" GHP**
  - Based on ASTM C177-85 specification
  - Capable of temperatures from -200°F to 500°F
  - Effective for testing insulating foams, graphite foams, fibrous insulations, low density ceramic insulations, cloths and rubbers



Impact Foam Samples, Test Matrix

110-XTHT Crushed Sample



- **Test samples**
  - 0.25” thick, 2” diameter
  - 0.005” diameter thermocouples
- **Foams tested, virgin and crushed properties**

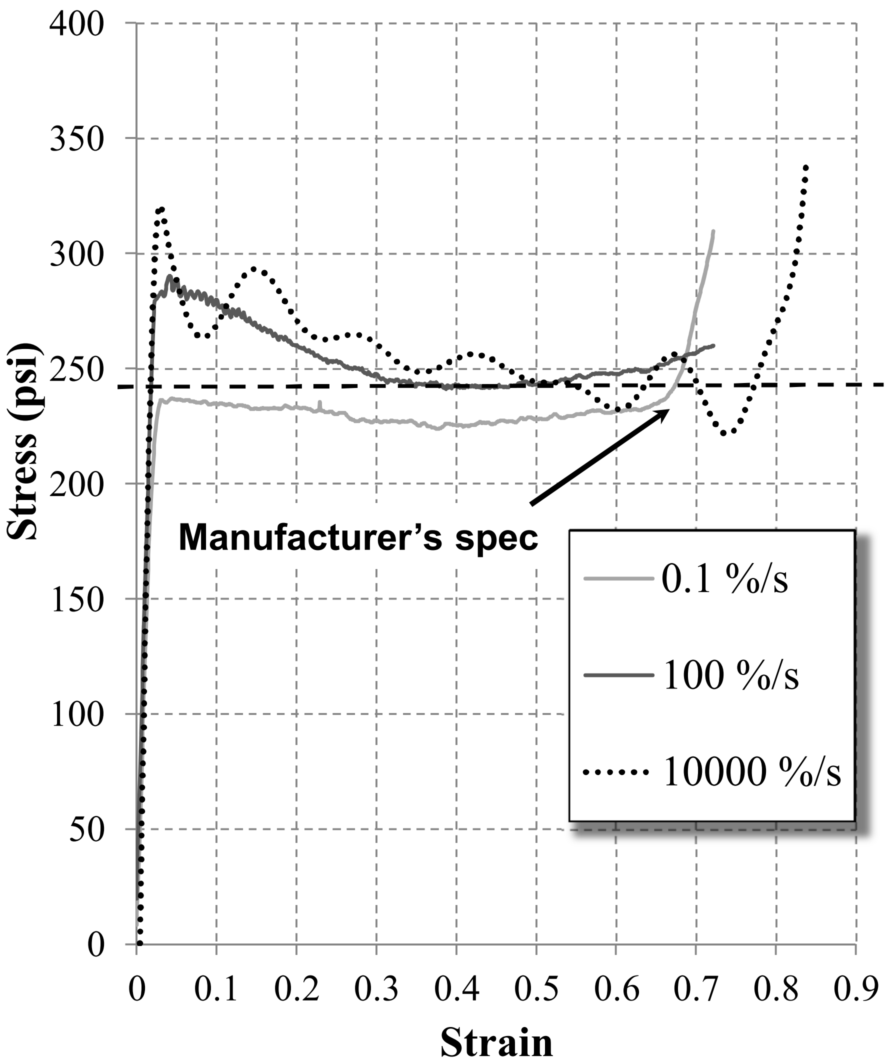
#	Foam	Density slugs/ft^3	σ_{cs} ksi	σ_{ss} ksi	T_d °F
1	71-WFHT	0.15	0.25	0.19	392
2	110-XTHT	0.21	0.52	0.35	464
3	71-WFHT-crushed	0.32	-	-	-
4	110-XTHT-crushed	0.40	-	-	-

- **Test Matrix**

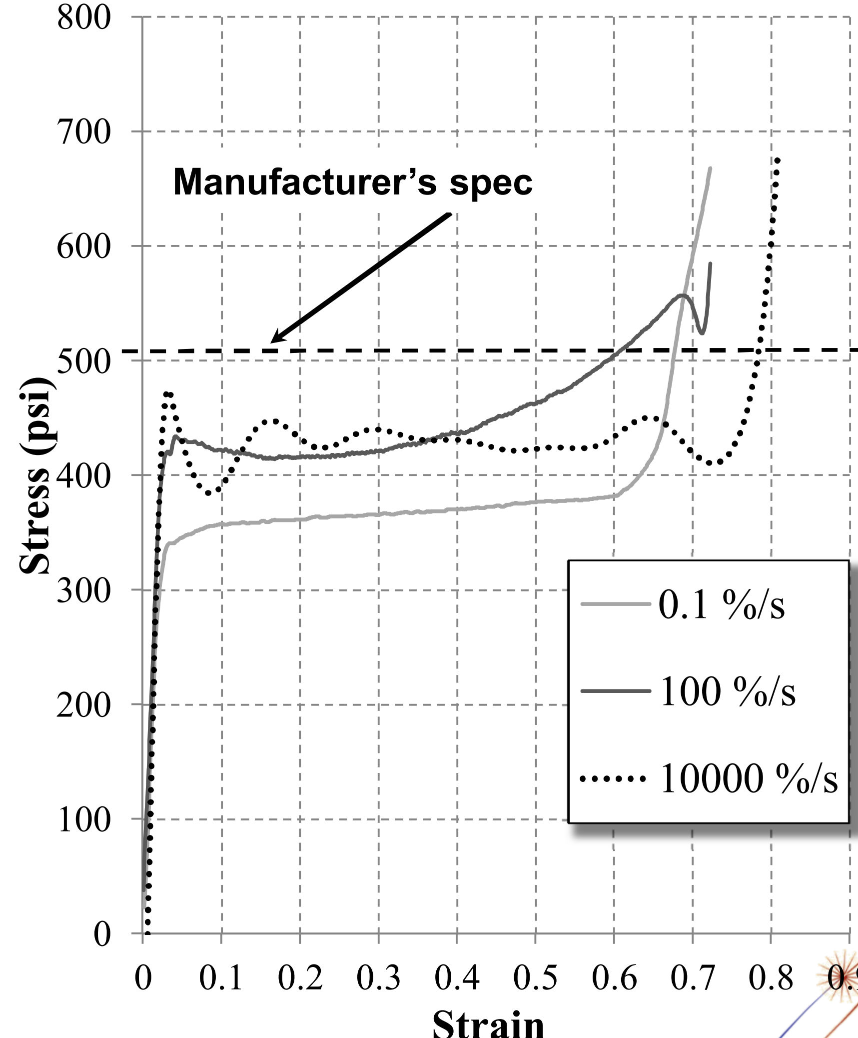
#	Foam	Condition	Test Pressure	Temperatures Tested
1	71-WFHT	Virgin	1 ATM	Multiple
2	71-WFHT	Virgin	Vacuum	Single
3	71-WFHT	Crushed	1 ATM	Multiple
4	71-WFHT	Crushed	Vacuum	Multiple
5	110-XTHT	Virgin	1 ATM	Multiple
6	110-XTHT	Virgin	Vacuum	Single Temp
7	110-XTHT	Crushed	1 ATM	Multiple
8	110-XTHT	Crushed	Vacuum	Multiple

Mechanical Properties of the Impact Foams Tested

71-WFHT

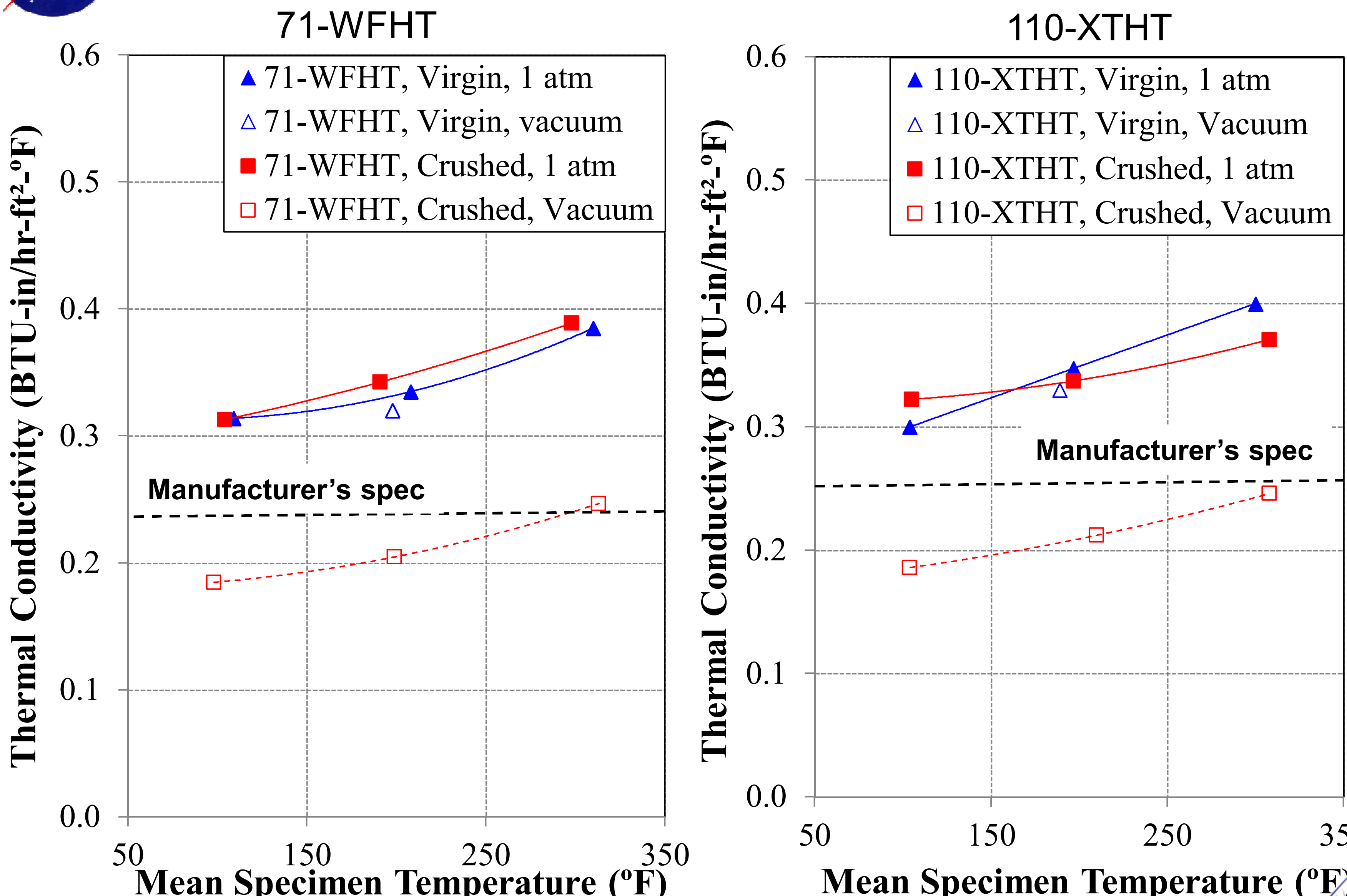


110-XTHT



Reference 6: Patterson and Glaab, 2012.

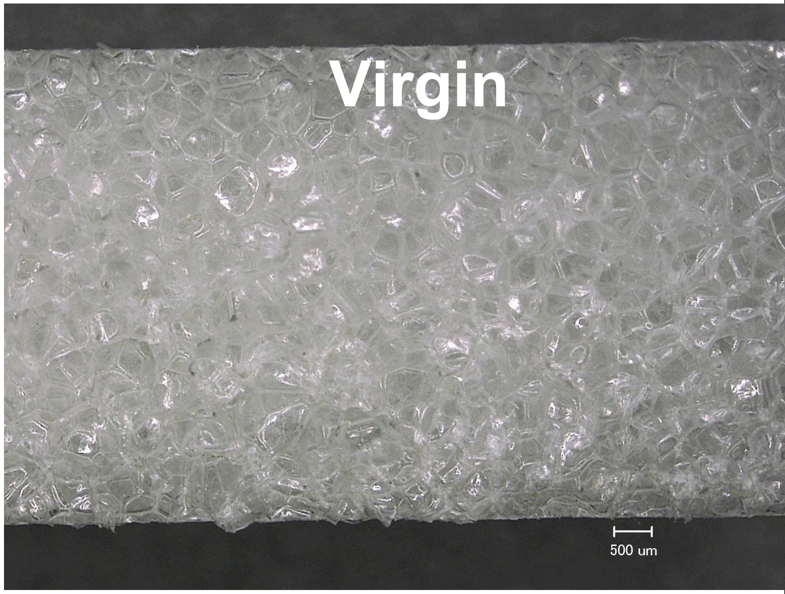
Thermal Conductivity of the Impact Foams Tested



IN-SPACE PROPULSION

Effect of Impact on Foam Thermal Conductivity

- Effect of impact
  - Crushes cells
  - Increases density
  - Small change in thermal conductivity
- Effect of vacuum testing
  - No effect for virgin foam
  - Large effect for crushed foam
  - Likely due to venting of manufacturing gas and replacement with air



Summary, Conclusions, Plans

- **A series of Rohacell foams were tested to determine their characteristics for MMEEV impact attenuation applications**
- **Results indicate good mechanical characteristics for a range of impact rates**
- **Thermal conductivity results**
  - Indicate the effect of impact is small
  - Likely due to venting of manufacturing gas and replenishment with air
  - Density is increased by a factor of two due to impact
  - Virgin thermal conductivity higher than manufacturer's specification
    - ~30% higher at low temperatures
    - ~60% higher at high temperatures
- **Plans**
  - Incorporate impact foam thermal conductivity data into thermal soak analyses
  - Complete modeling in support of parametric Multi-Mission System Analysis for Planetary Entry (M-SAPE) tool (Reference 2).

BACKUP

Effect of Foam Density on Thermal Soak