



Entry Systems and Technology Division
Ames Research Center

National Aeronautics and
Space Administration



Modernizing High Temperature Reusable Entry Materials

Austin Hacker

August 2023

Context

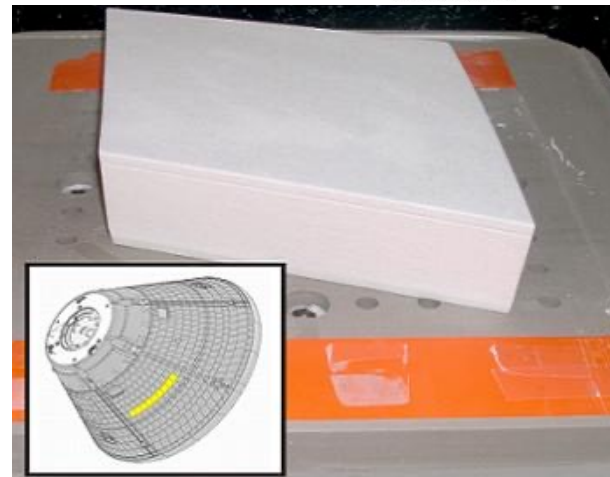
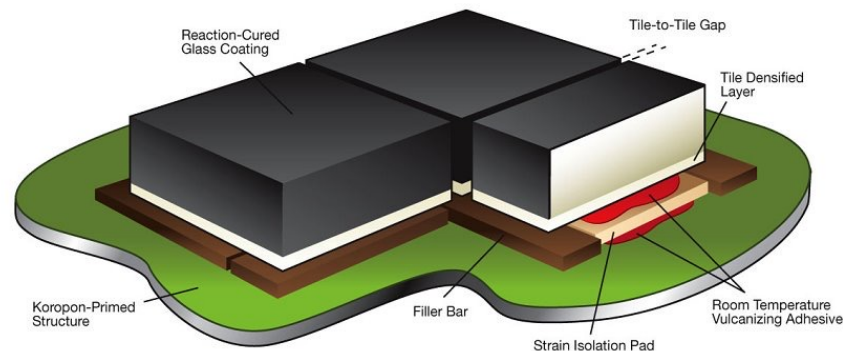


- Context
 - Resurgence in reusable thermal protection systems (TPS)
 - AETB (Shuttle Tile) is made using heritage material from lifetime buy, urgency to validate modern raw materials
 - NASA is running out of AETB, once we are out, we are unable to create more
- Motivation
 - Help NASA
 - Orion
 - Help commercial space
 - SpaceX, Blue Origin, Sierra Nevada
 - Develop next generation of reusable TPS
 - Investigate how procedure informs property
 - Deeper understanding of correlating factors -> more control of TPS Design

Alumina Enhanced Thermal Barrier (AETB)



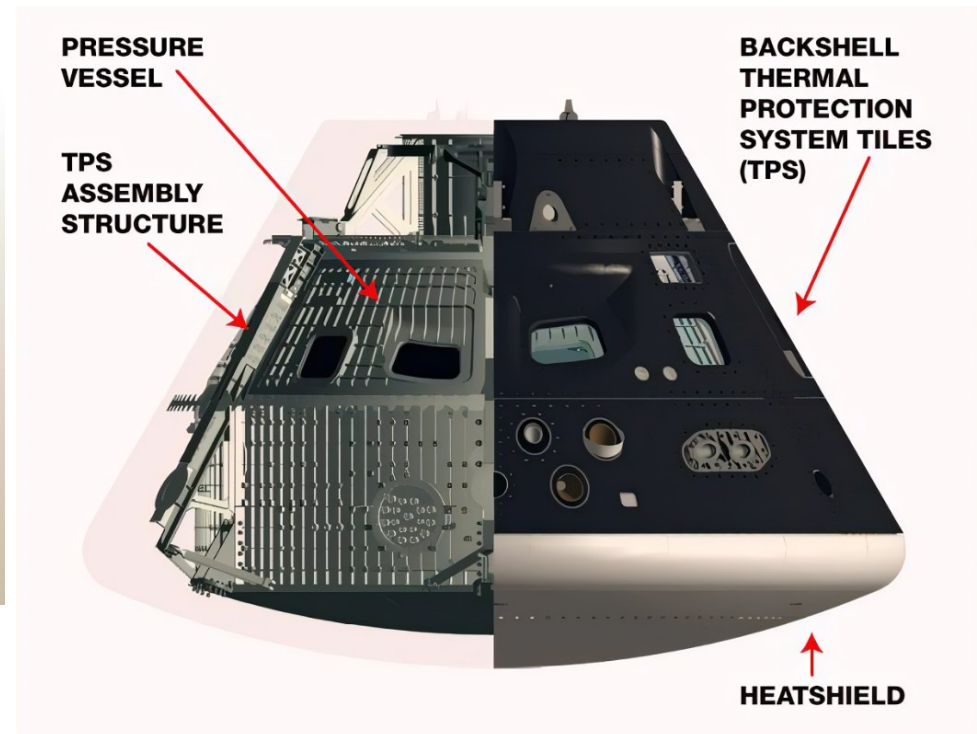
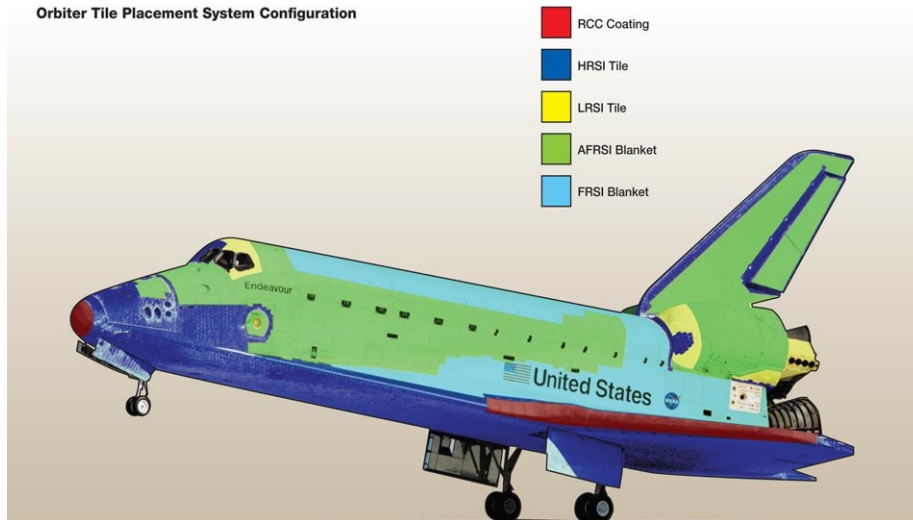
- AETB-8, -12, -17, -20 (lbs/ft³)
- Low-density, ceramic tile
- Fibrous thermal insulator
- Composition
 - Silica fibers
 - Aluminumborosilicate fibers
 - Alumina fibers
 - Silicon Carbide
- Best dimensional stability of the HTRM tile materials
- The golden standard
 - Arcjet testing
 - Companies interested
 - Best mechanical strength to thermal insulation tradeoffs
- Use up to ~2800 °F (single use)



Alumina Enhanced Thermal Barrier (AETB)



Orbiter Tile Placement System Configuration



Process



1. New batch of ingredients



2. Mix into wet slurry

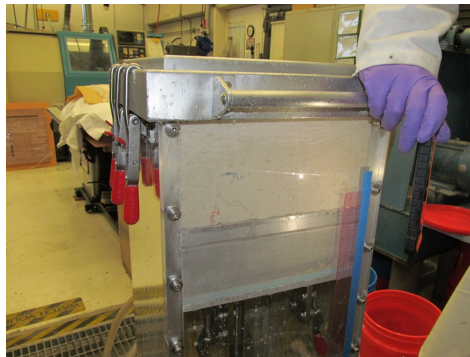


3. Chop in V-blender

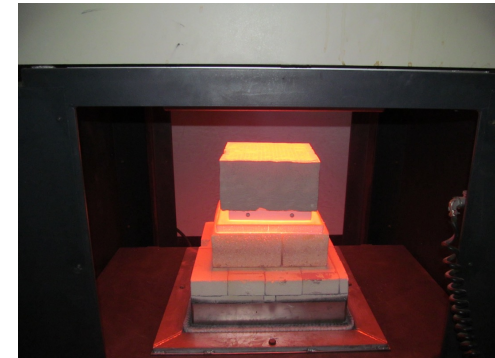


4. Pour into casting tower

August 11, 2023

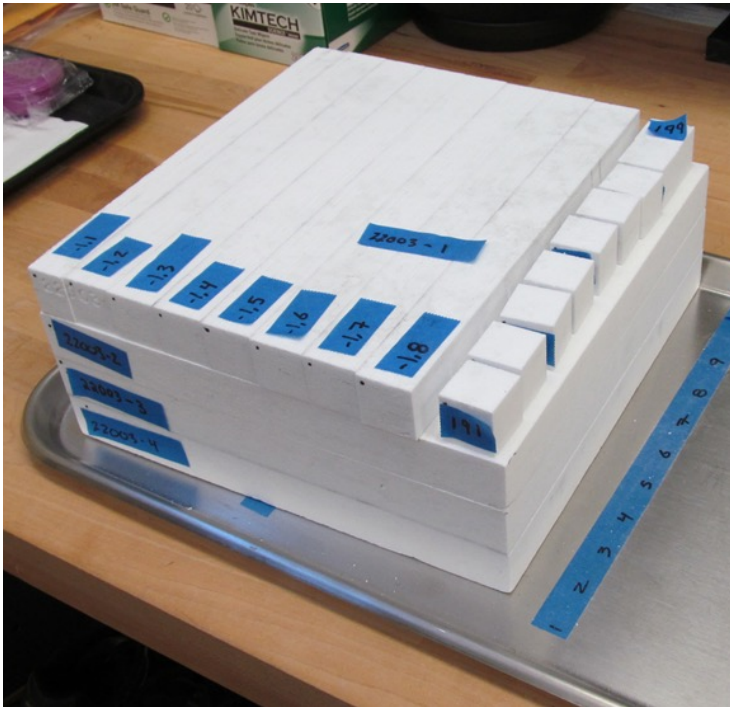


5. Compress and vacuum out water into wet billet



6. Dry, then fire, sintering the fibers

Characterization



AETB trimmed billet cut into sheets, rods, and 1" cube articles for testing

Primary – correlate to thermal conductivity

- Shrinkage
- Tensile strength
- Density

Secondary – supports primary characterization

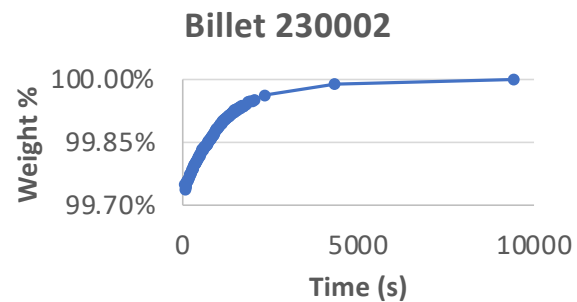
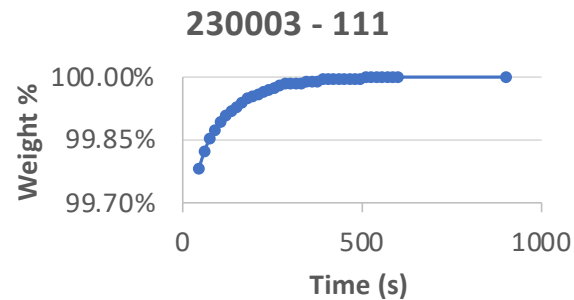
- Water absorption

Article Characterization tests



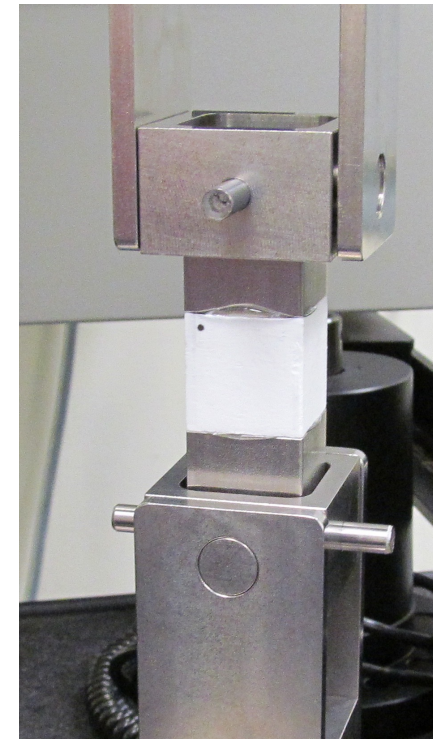
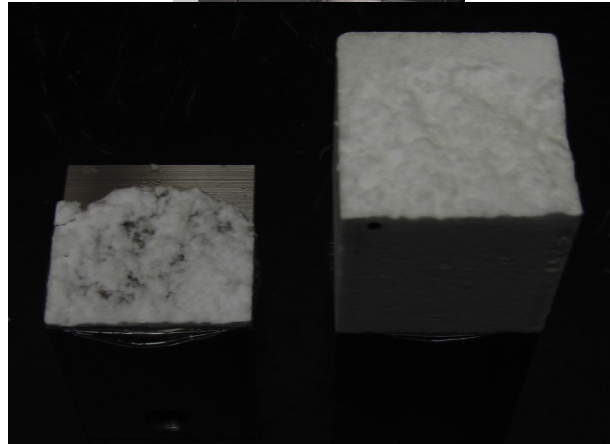
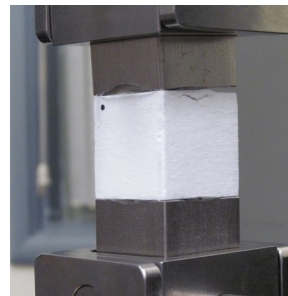
Water Absorption

- Relates weight as a function of time
 - Good for ensuring standard testing conditions

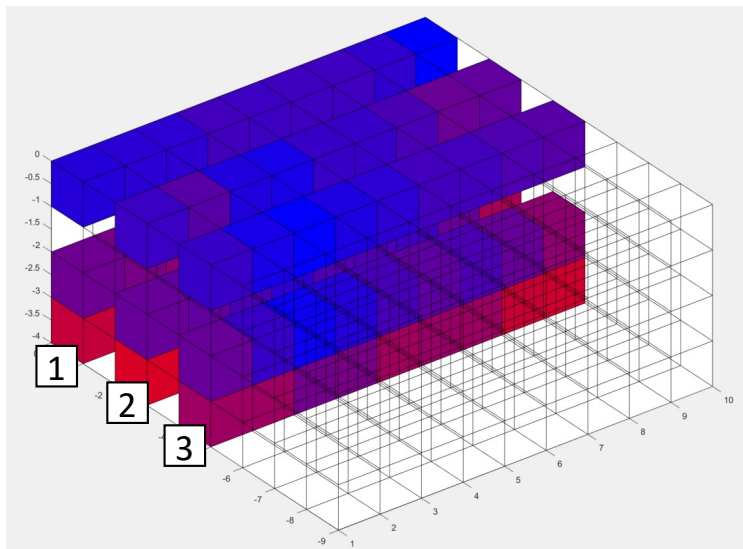


Tensile Strength

- Directly correlates to thermal performance



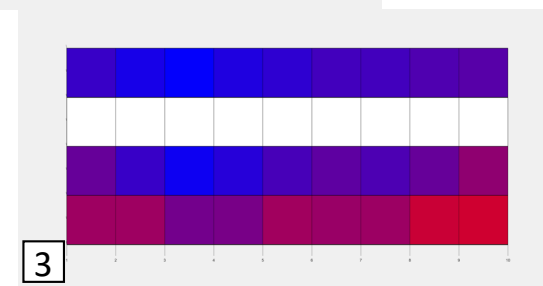
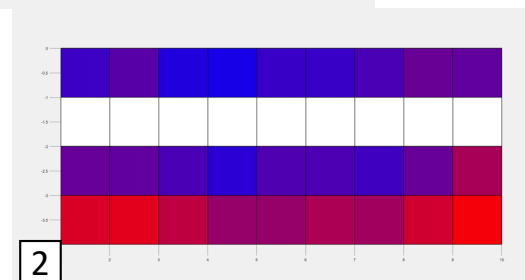
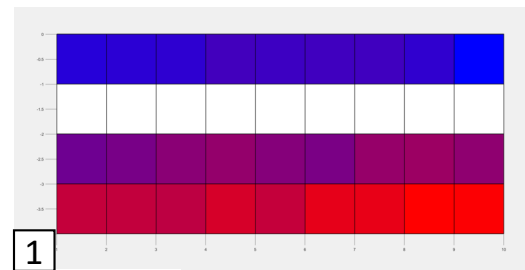
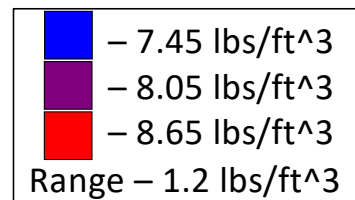
Density Measurements



Billet Bulk Density – **7.90 lbs/ft³**

Density is the most efficient
marker of thermal/mechanical
properties

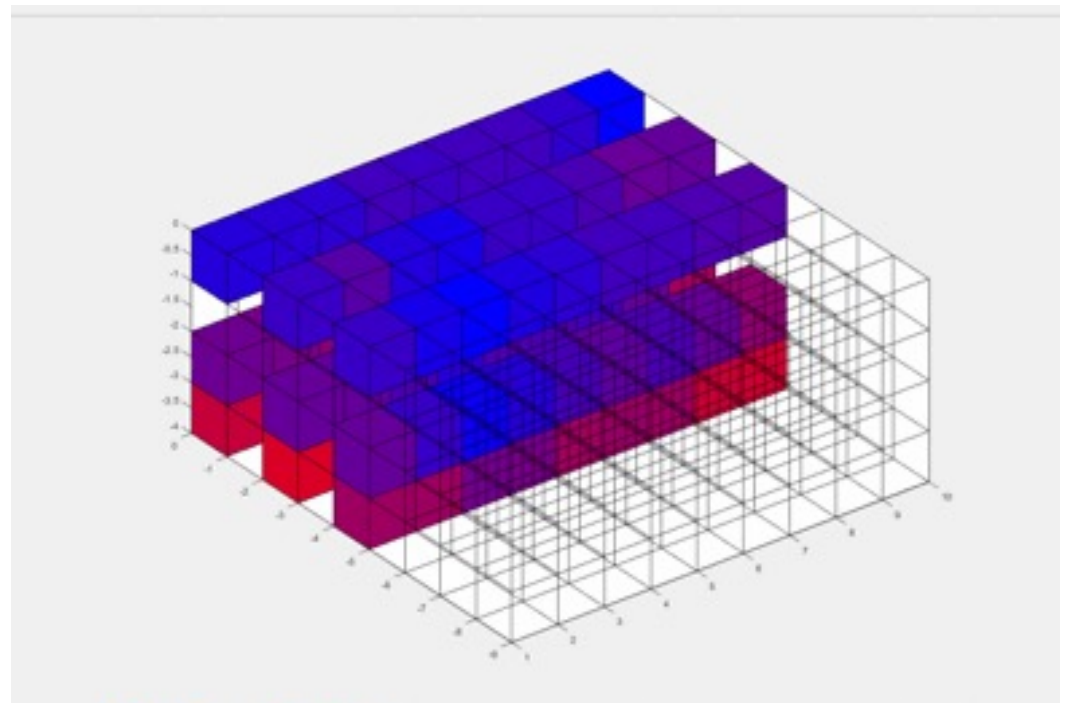
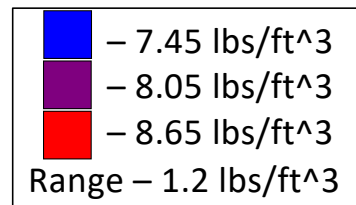
August 11, 2023



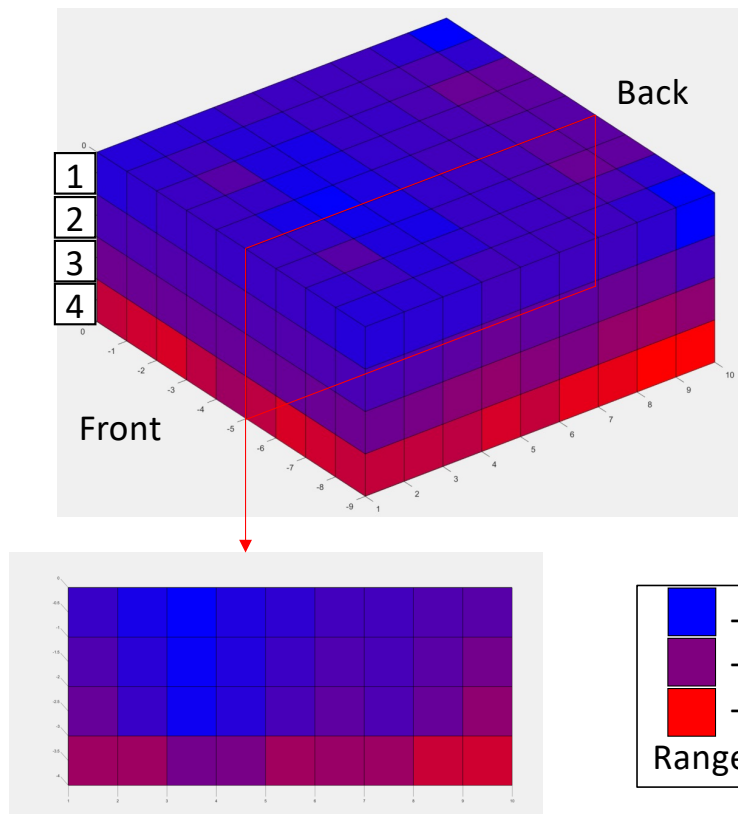
Extrapolating



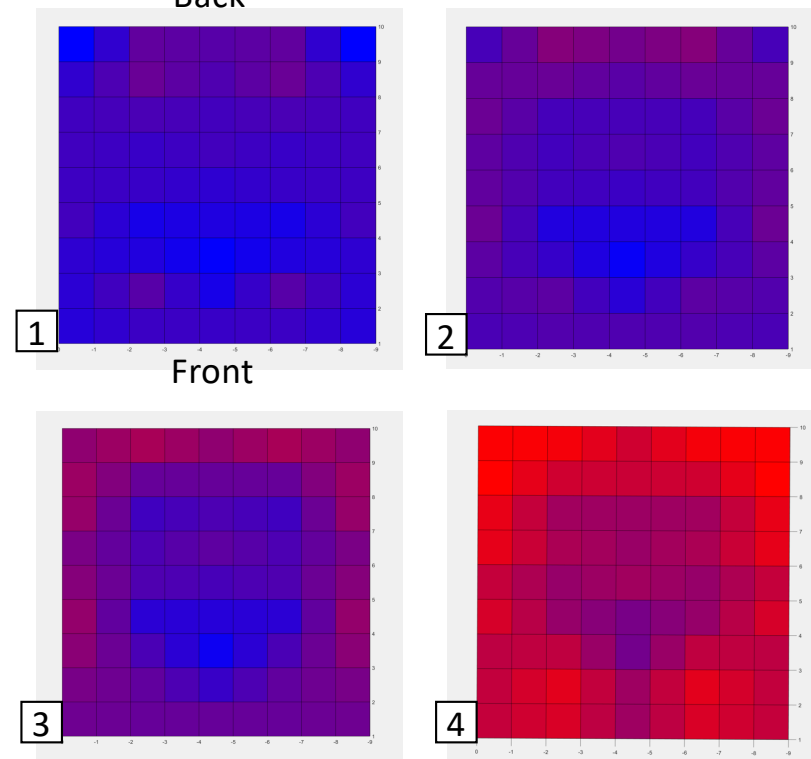
- Assumed symmetrical lateral heat load
 - Mirrored
- Extrapolated average data into adjacent cells



Extrapolated Density Measurements



Top View of Sheets

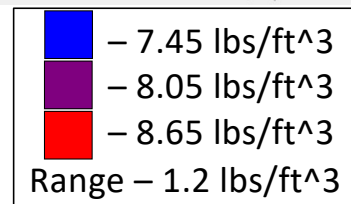
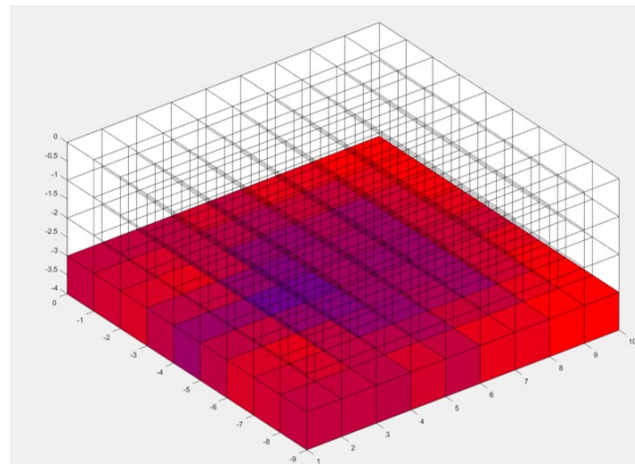


Trends

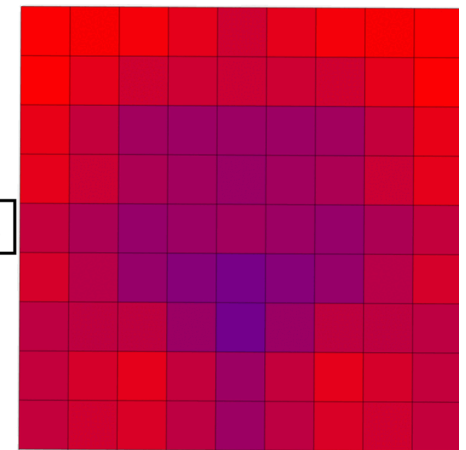


Trends

- Radial density gradient
- Denser in back & bottom, shows bias in furnace heat distribution
- Need more article data
 - Large time sink



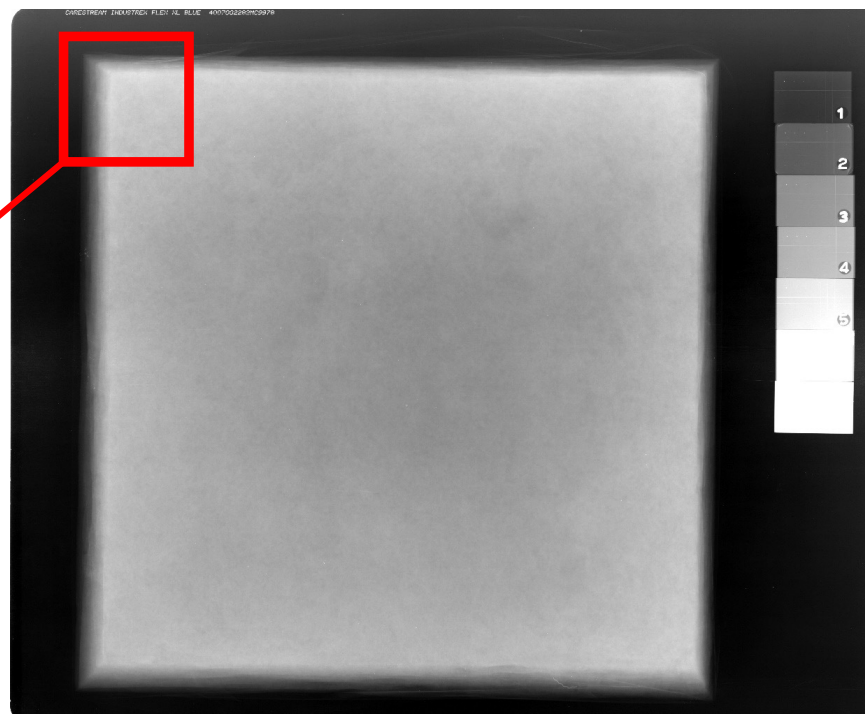
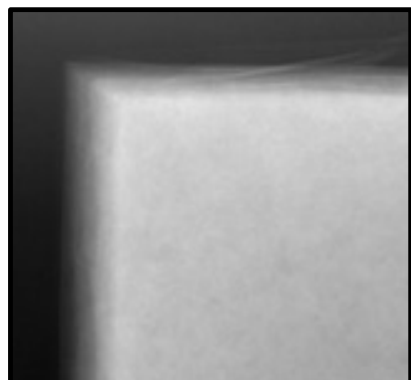
4



Xray Density Gradient



- Need cube method to progress to Xray method
- More continuous density profile than cube method
- Fraction of the time it takes to machine cubes
- Easier to view boundary defects

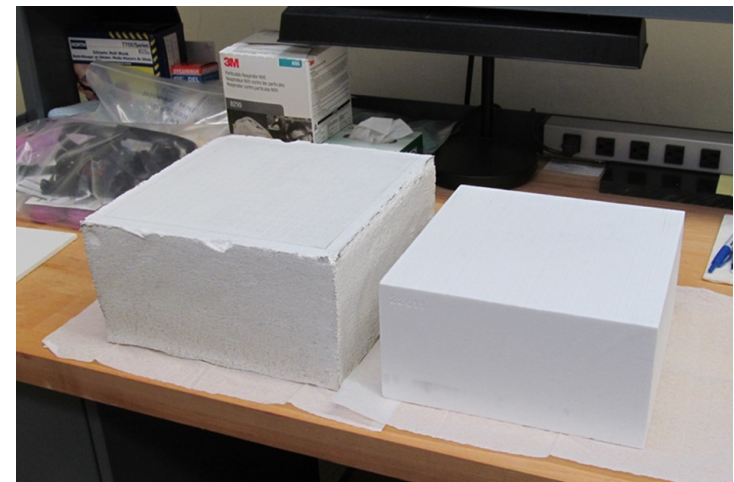


August 11, 2023

AETB Billet



- Untrimmed– 705 g
- Untrimmed to Trimmed Billet – 488 g, 31% **initial weight loss**
- Trimmed to Cubed Billet- 315 g, 35% weight loss
- **55% total weight loss**, majority from denser, external skin region
 - Excessive material waste
 - Reduces test volume
 - More discrete density gradient characterization
 - Removes skin region information
- Skin Region
 - Majority of Billet Defects
 - Densest region
 - Must be removed for billet usage
 - X-ray method allows us to characterize it

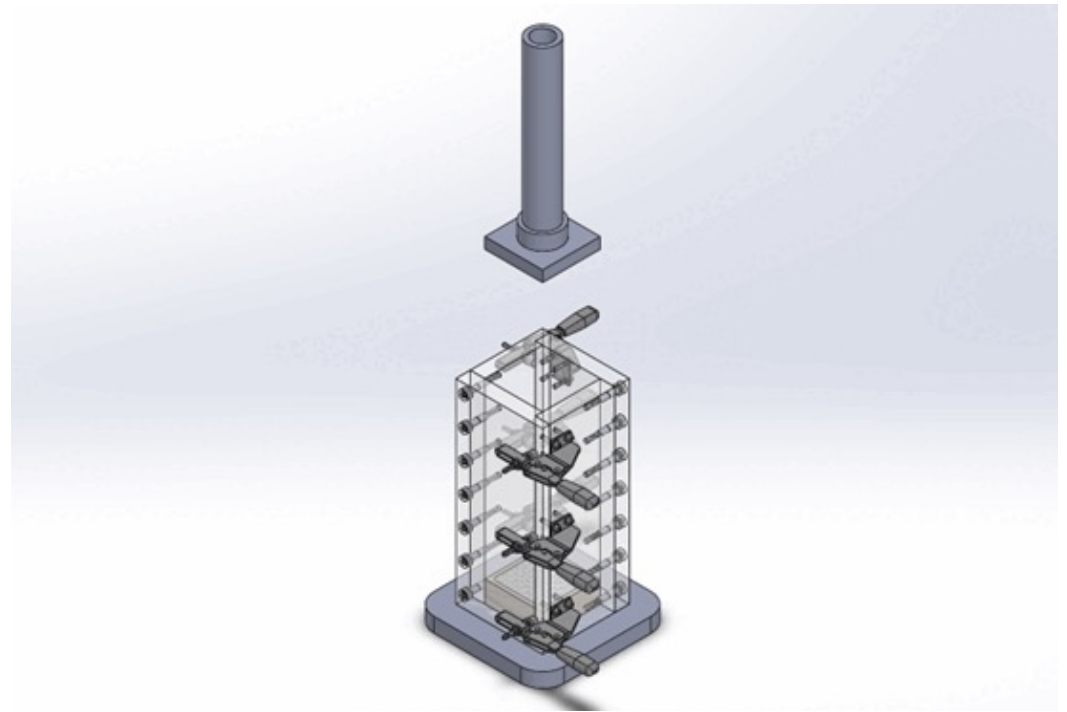


12"x12"x6" Untrimmed vs. 10"x10"x5"
Trimmed AETB Billet

4" Tile Caster



- Quicker billet development time
- Less billet material used -> cheaper
- Increases efficiency in determining factors contributing to tile thermal and mechanical properties



Next Steps



- Finish method development
- Further work
 - Test using quicker turnaround, 4" billet casting tower
 - Validate new materials compared to heritage materials
 - Tensile Testing
 - Optical & Electron Microscopy
 - Density Gradient Measurements
 - Cubed article method
 - Xray method
 - Thermocoupled billet
- Further explore process to property correlation



Entry Systems and Technology Division
Ames Research Center

National Aeronautics and
Space Administration

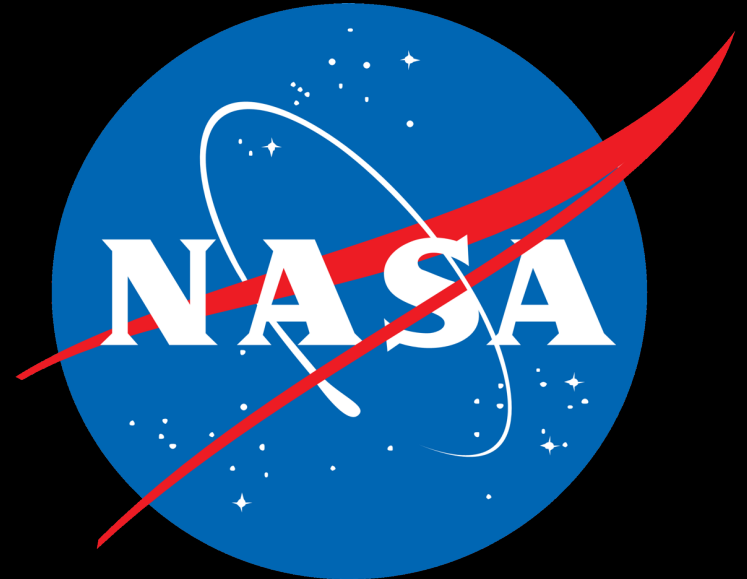


Questions?

August 11, 2023

16

National Aeronautics and Space
Administration



Ames Research Center
Entry Systems and Technology Division