AN UPDATE ON STRUCTURAL SEAL DEVELOPMENT AT NASA GRC

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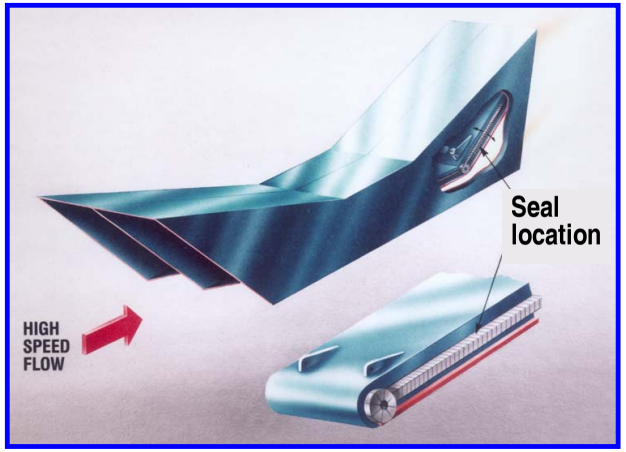
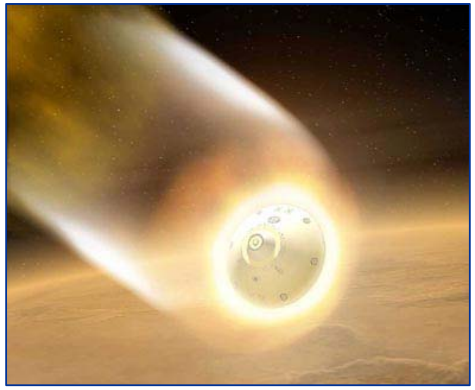
Introduction & Background

- Advanced structural seals are required on future hypersonic vehicles and on vehicles and systems for NASA's Exploration Initiative
  - Dynamic seals:
    - Control surfaces
    - Landing gear doors
    - Access panels and doors
    - Hypersonic engine ramps and panels
  - Static seals:
    - Docking/berthing system seals
    - Leading edge panel joints
    - Acreage thermal protection system (TPS) joints
    - Heatshield joints and interfaces

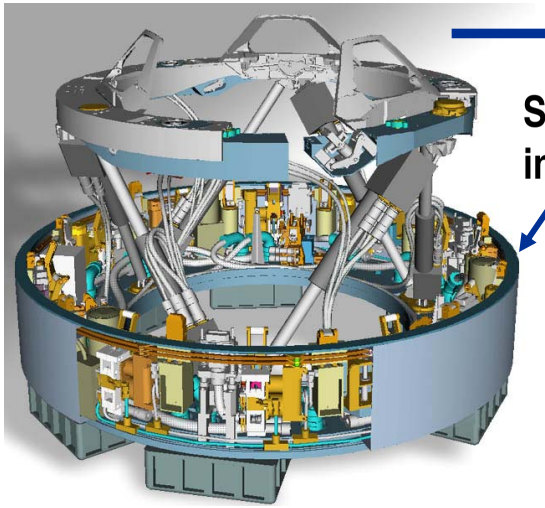


Hypersonic engine seals

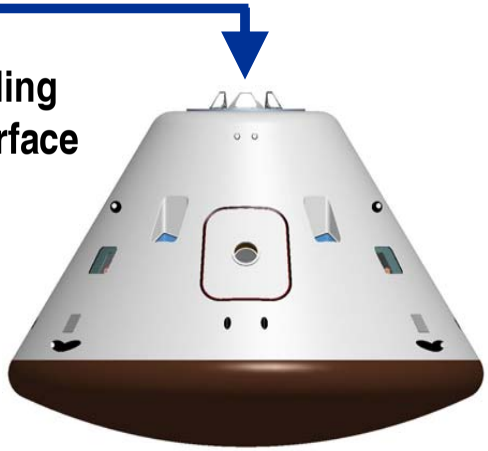


Heatshield seals

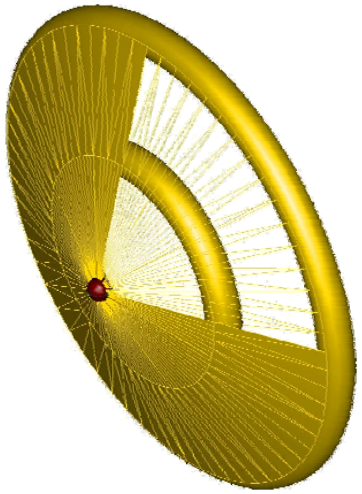
GRC Structural Seals Team Research Areas



Advanced Docking/Berthing System



Crew Exploration Vehicle (CEV)

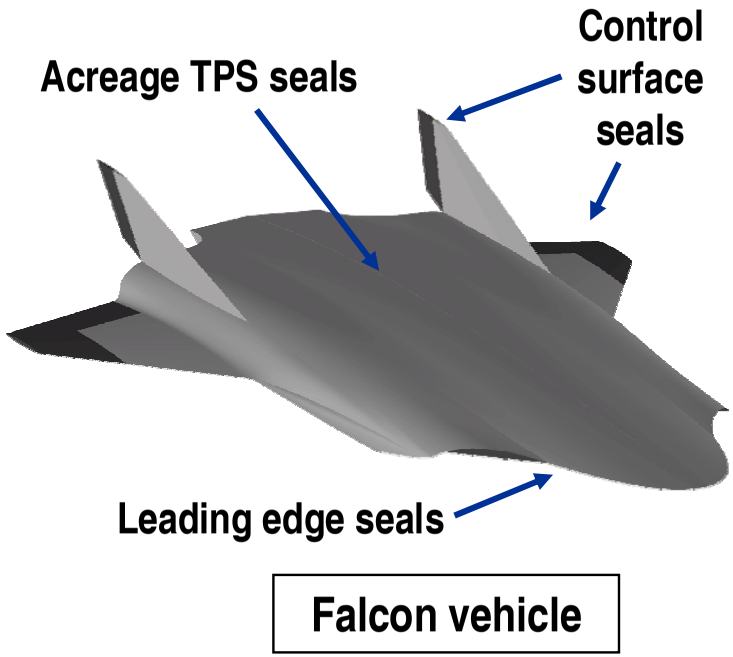


Trailing ballute for aerocapture

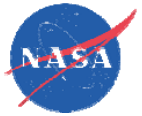
- GRC Structural Seals Team developing seals for NASA's Exploration Initiative:
  - Advanced Docking/Berthing System (ADBS) for CEV (JSC)
  - CEV TPS Advanced Development (LaRC, Ames)
  - Aerocapture Technology Development (MSFC)
  - Deployable Skirt System (Northrop Grumman)

Research Areas & Objective

- GRC Structural Seals Team also developing seals for hypersonics programs:
  - Falcon program (Lockheed Martin, DARPA, JSC)
  - X-43C Direct Connect Combustor Rig (ATK GASL, LaRC)



Objective: Develop sealing systems that meet vehicle/system requirements and demonstrate performance in relevant environments



Presentation Outline

- Wafer seals
- Spring tube seals
- High temperature seal preloaders: TZM canted coil springs
- Arc jet test rig

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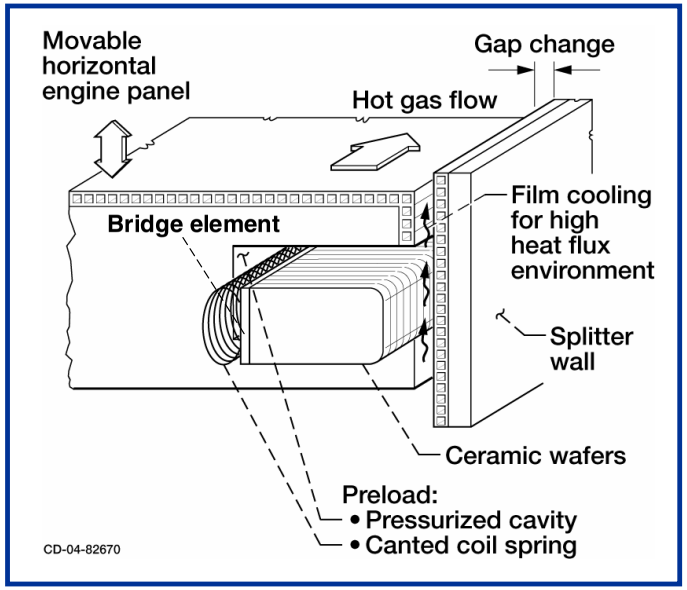
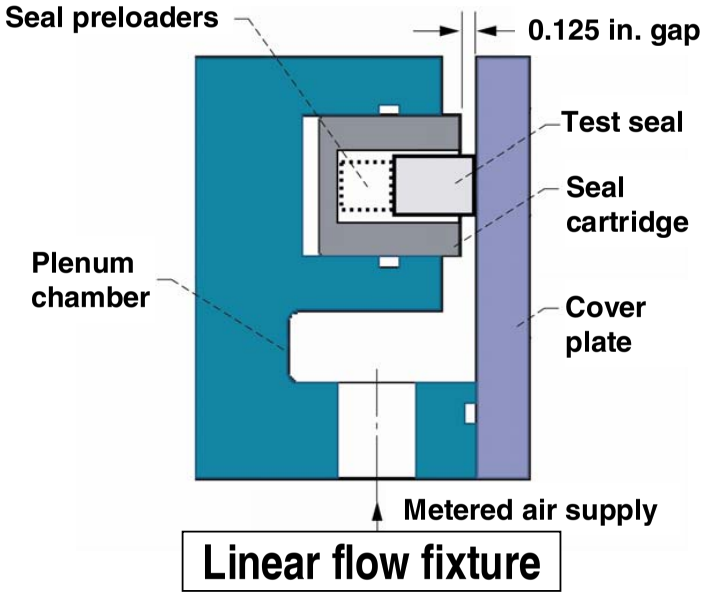
Wafer Seal Geometry/Flow Investigations

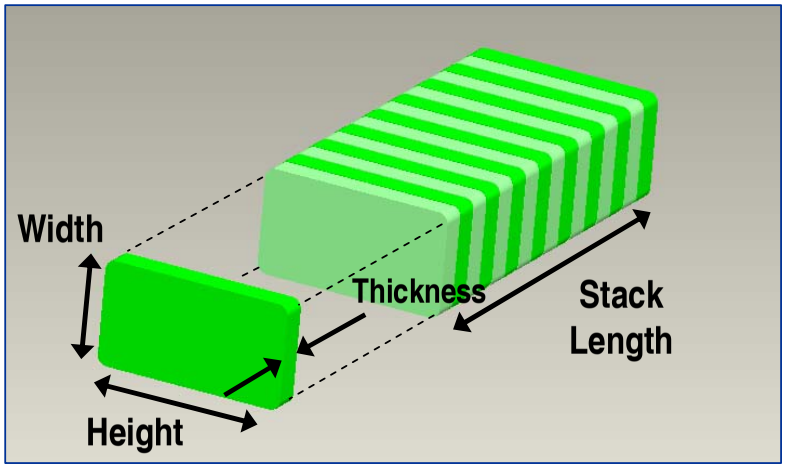


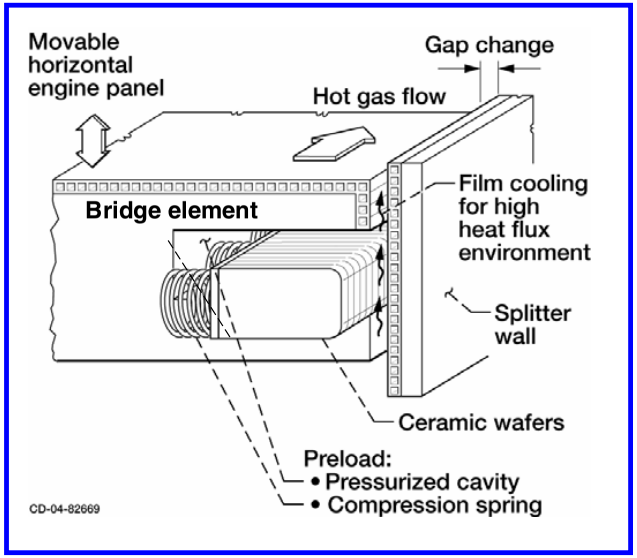


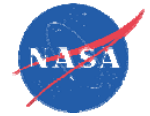
- Previous tests revealed that wafer seal installation factors influenced flow rates
- Objective: Improve understanding of wafer sealing system
- Approach: Parametric studies of performance (flow tests)
  - Design of experiments (DOE) study to evaluate variables that affect seal installation
  - Wafer seal geometry study

Wafer Seal Installation DOE Study

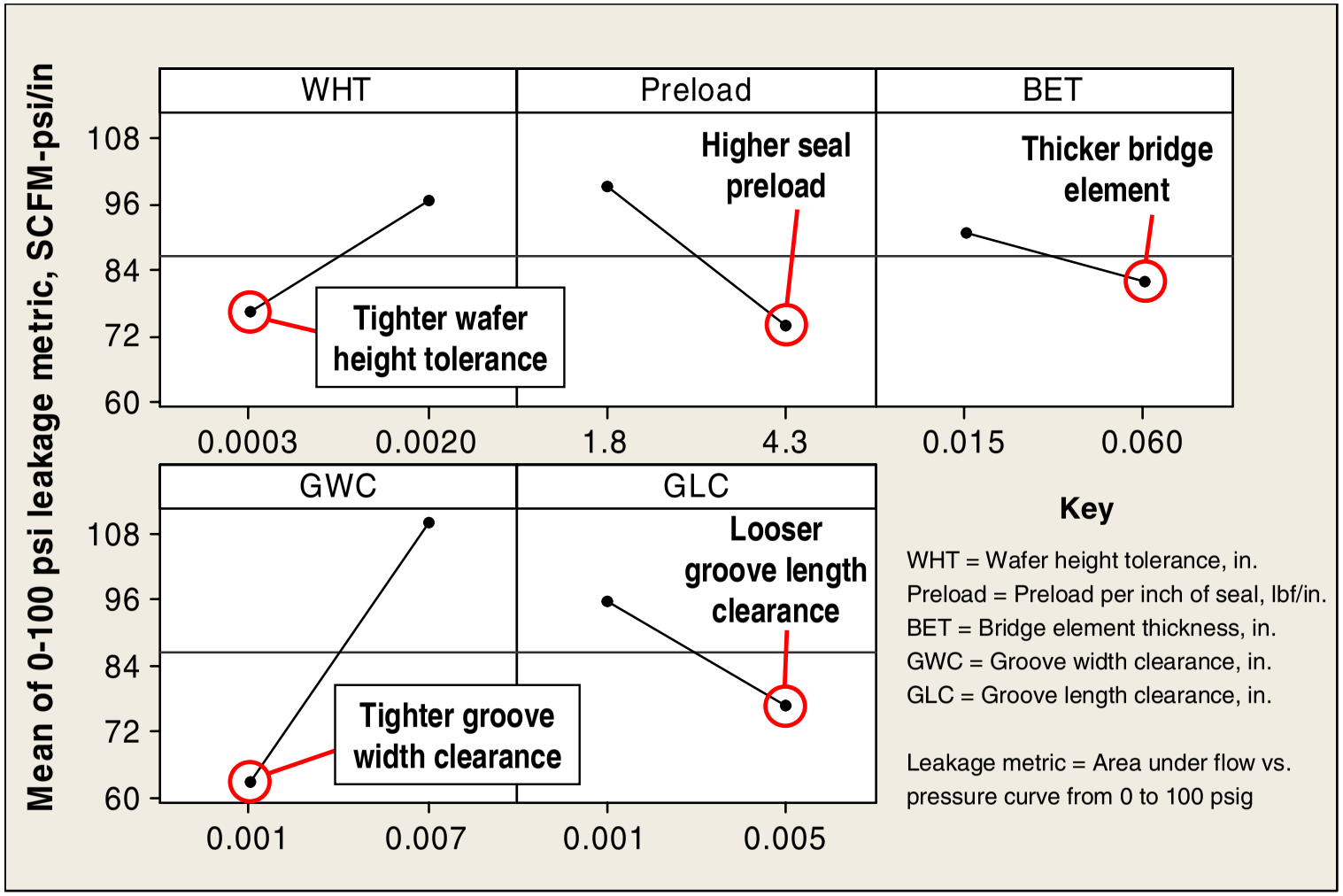
- Wafer geometry: 0.5 in. wide x 0.92 in. long x 0.125 in. thick
- Five factors evaluated at two levels
  - Wafer height tolerance: 0.0003 and 0.0020 in.
  - Preload: 1.8 and 4.3 lbf per inch of seal
  - Bridge element thickness: 0.015 and 0.060 in.
  - Groove width clearance: 0.001 and 0.007 in.
  - Groove length clearance: 0.001 and 0.005 in.
- Test matrix:
  - 16 trials
  - Fractional factorial design (Resolution V)
  - Tests performed in random order to minimize biases







Results of Wafer Seal Installation DOE Study



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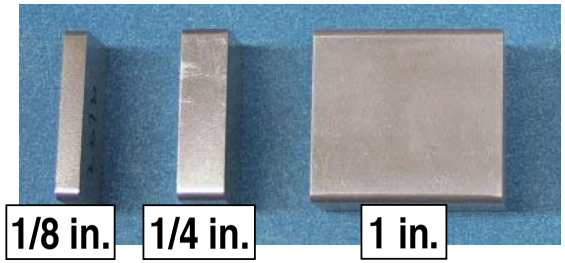
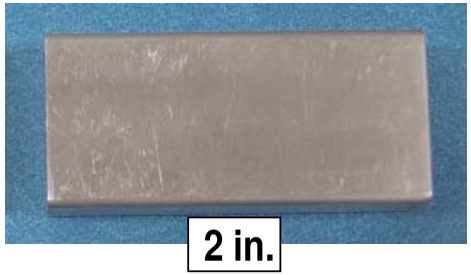
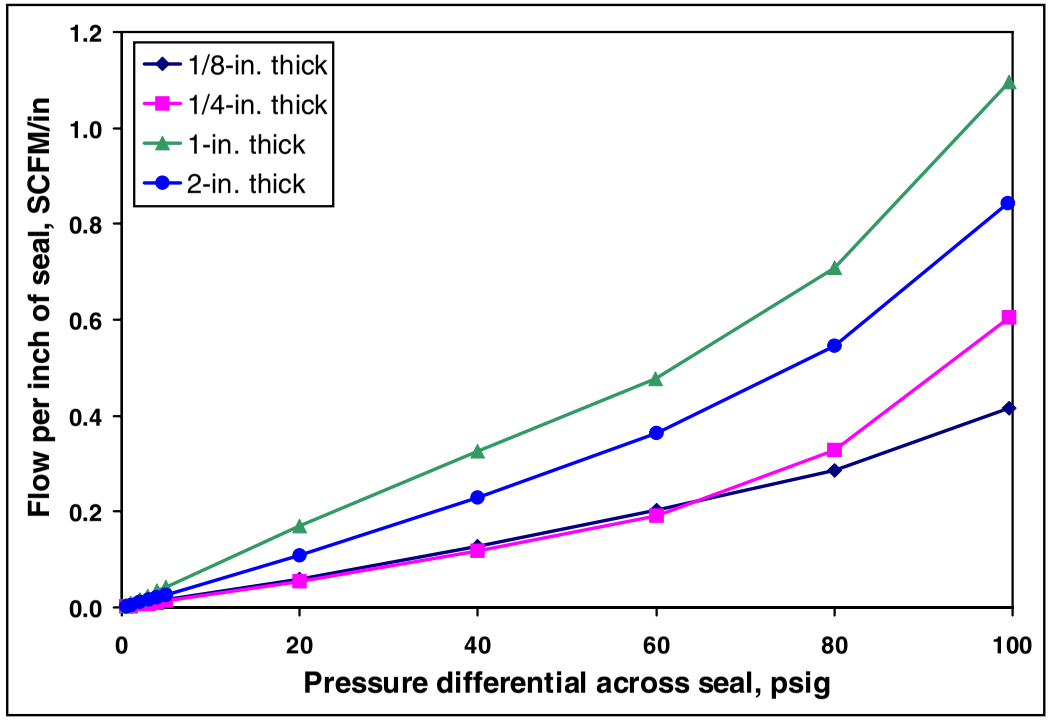
Wafer Geometry Study: Thickness Variations







- Motivation: Thicker wafers have lower part count, lower leakage rates?
- Comparable leakage rates for 1/8-in. and 1/4-in. thick wafers: can reduce part count 2X by using 1/4-in. thick wafers
- Higher flow rates for 1-in. and 2-in. thick wafers, less able to conform to wafer misalignments and sealing surface distortions

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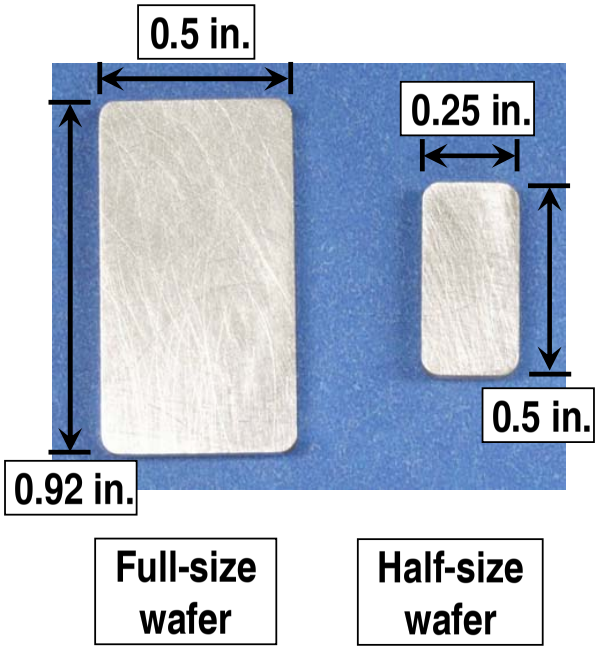
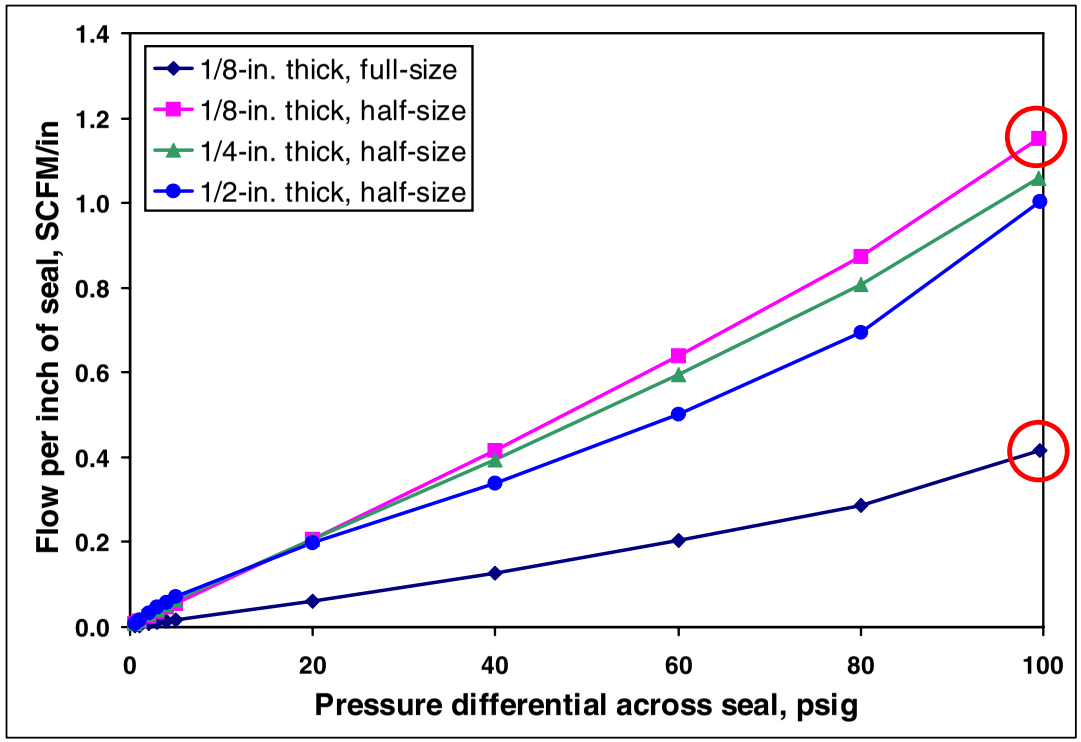
Wafer Geometry Study: Full-Size vs. Half-Size Wafers

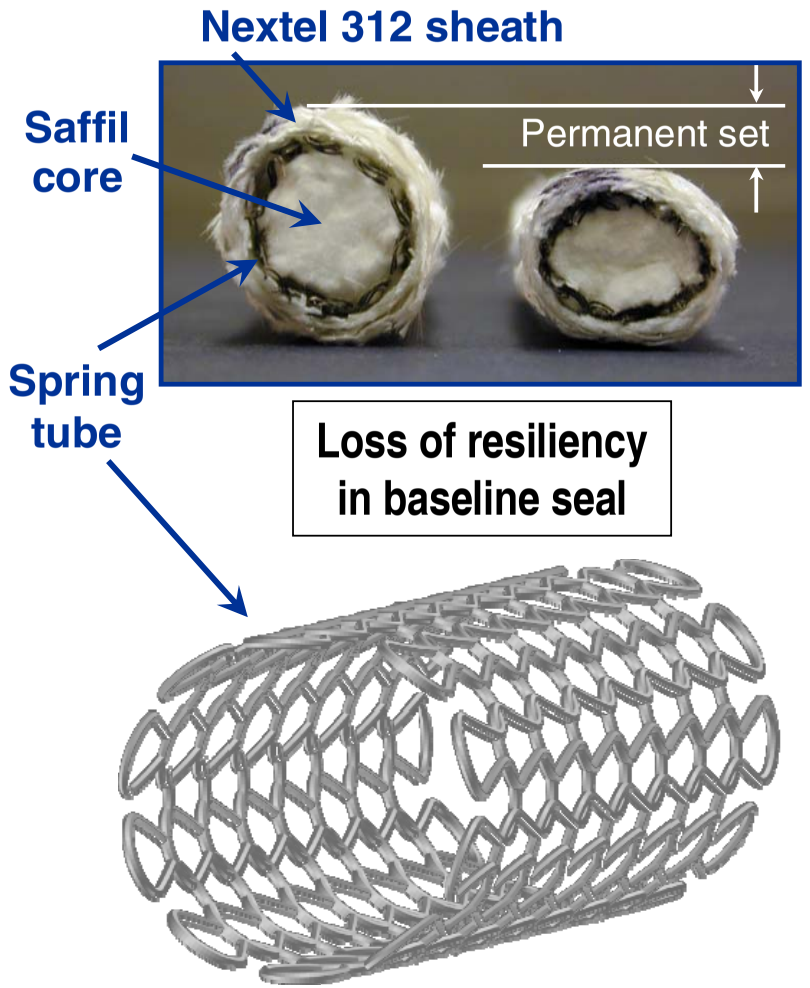




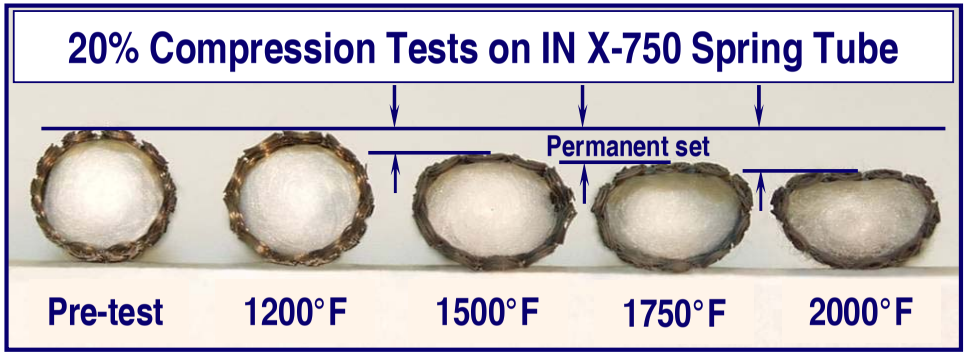
- Motivation: Smaller wafers occupy less space, weigh less, fit in tighter locations
- Flow rates for half-size wafers ~3X those for full-size wafers (1/8-in. thick)
- Can reduce part count 4X for half-size wafers by using 1/2-in. thick wafers vs. 1/8-in. thick (similar flow rates)

Spring Tube Seal Development

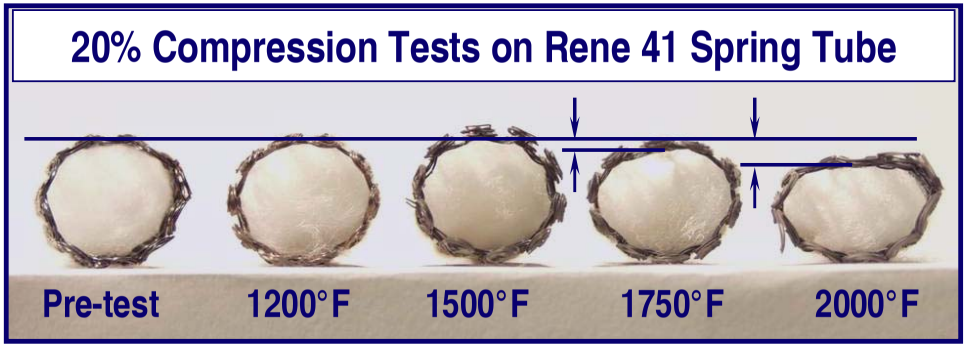
- Objective: Improve resiliency of spring tube seals at high temperatures
- Approach: Substitute Rene 41 as material for knitted spring tube vs. Inconel X-750 in baseline design



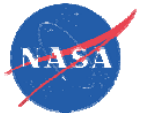
Resiliency Improvement for Rene 41 Spring Tube



Significant permanent set for Inconel at 1500°F



No visible permanent set for Rene until 1750°F



Spring Tube Seals: Go-Forward Plan

- Testing to-date has been on spring tubes by themselves
- Work in progress:
  - Fabricating seals with Rene 41 spring tubes for evaluation (Jackson Bond Enterprises, LLC)
- Future work
  - Perform hot compression tests on new seals to evaluate if resiliency improvements translate to full seals
  - Fabricate and evaluate seals with Kanthal A1 wire overbraid instead of Nextel fabric (improved durability)
  - Fabricate and evaluate seals with engineered cores instead of Saffil (improved resiliency and lower flow rates)

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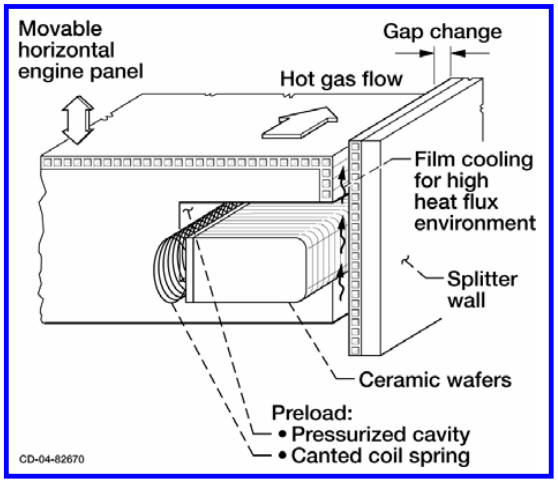
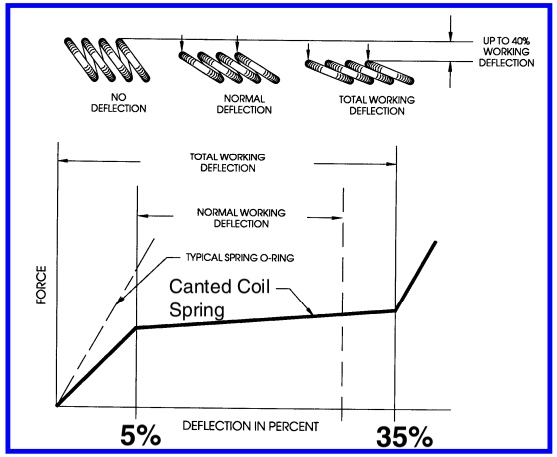
High Temperature Seal Preloader Development: TZM Canted Coil Spring

- Objective: Develop preload devices that provide/augment seal resiliency at high temperatures
- Approach: Pursuing high temperature TZM canted coil springs
  - Unique load vs. displacement curve provides nearly constant force over large range
  - Large working deflection

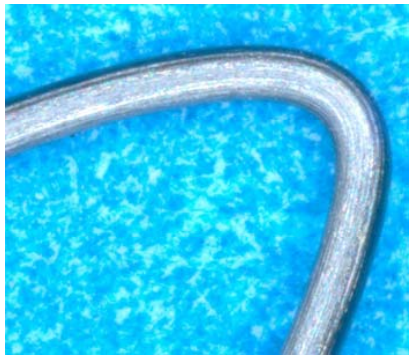




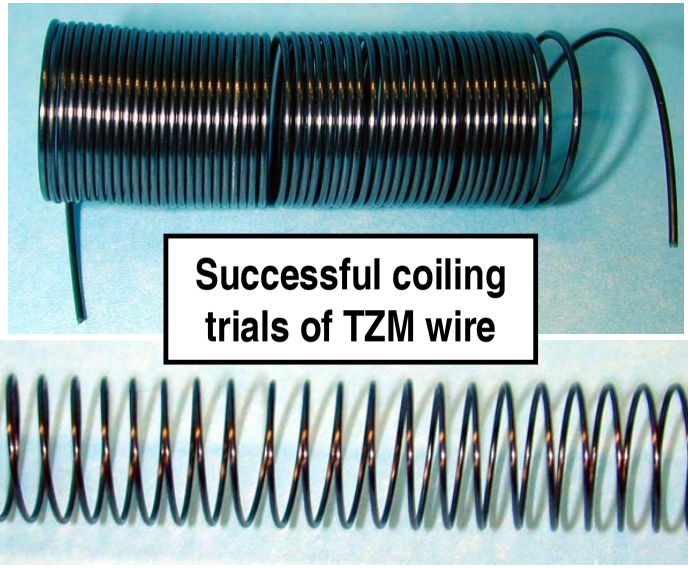
Large working deflection of canted coil spring

TZM Canted Coil Spring Development

- Recent accomplishments
  - Successfully fabricated split-free 0.025-in. diameter TZM wire with better than expected strength and ductility (Rhenium Alloys, Inc.)
  - Successfully cold-coiled TZM wire into representative spring geometries
- Work in progress
  - Wire coating trails using platinum
  - Wire tensile tests at room temperature and 2300°F
- Future work
  - Assess platinum coating durability via bend tests at 2300°F in air
  - Coil TZM wire into canted coil configuration and perform compression tests to evaluate resiliency



Split-free TZM wire



Successful coiling trials of TZM wire

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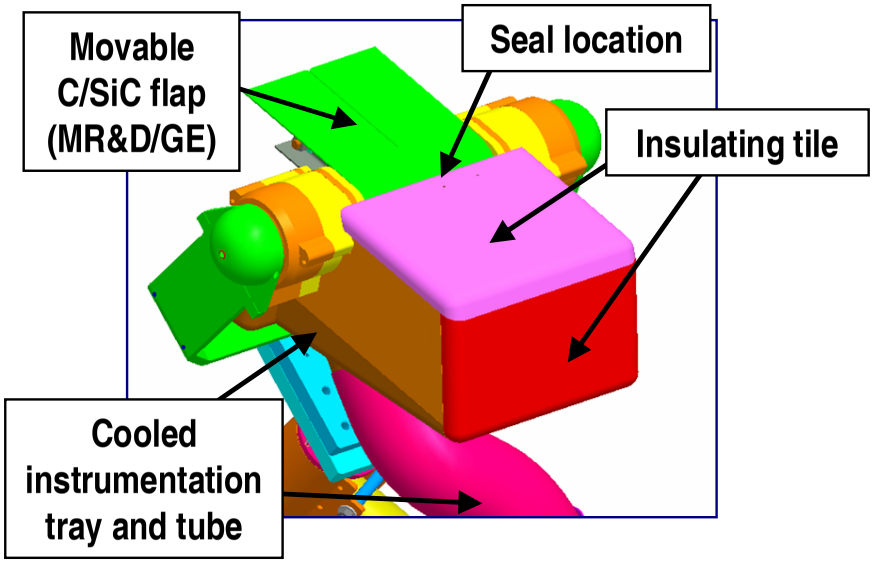
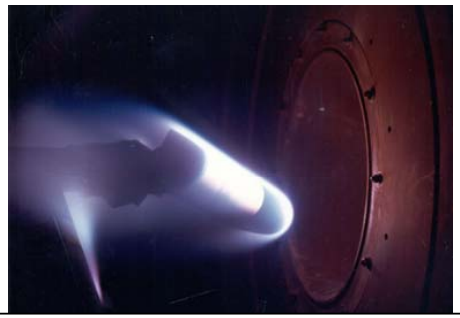
Arc Jet Test Rig Development

- Objective
  - Evaluate seals under simulated reentry heating conditions in JSC arc jet using GRC-developed test fixture
- Features
  - Unique GRC design permits testing of different seal and flap designs/materials
  - Modular seal cartridges enable rapid exchange of seal specimens
  - Motor-driven flap moves during testing to simulate flight
  - Adjustable angle-of-attack and yaw angle permit investigation of different flow conditions
  - Instrumentation records temperatures and pressures around seal and flap
  - Cooled subassembly permits time-at-temperature tests



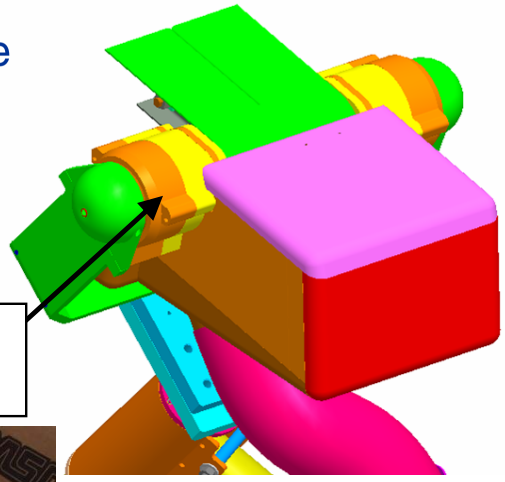


Typical arc jet test at JSC

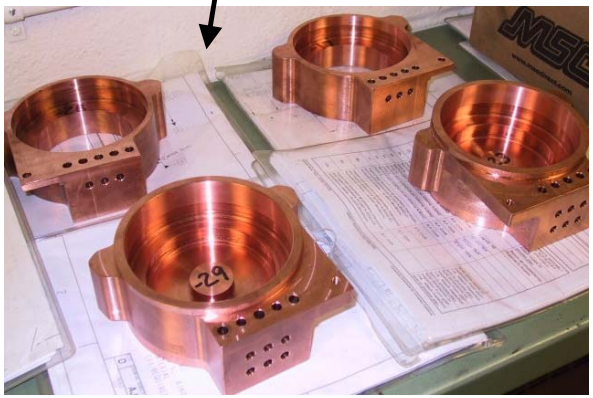
Arc Jet Test Rig – Status

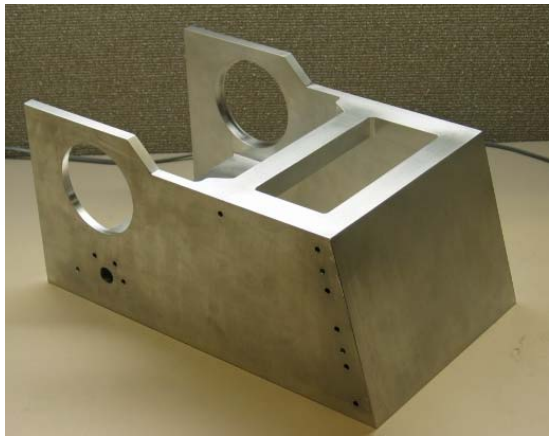
- Fabrication is underway (Cook Manufacturing Co.)
- Schedule:
  - Complete test fixture fabrication and assembly: 1Q FY06
  - Perform tests at JSC: FY06-07

Wax model of sidewall showing cooling channels

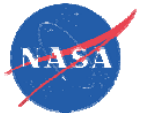


Cooled copper motor and brake housings





Aluminum mockup of leading edge



Summary

- GRC Structural Seals Team developing key seal technologies for NASA's Exploration Initiative and hypersonics programs
- More details in presentations to follow…

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