OVERVIEW OF CEV THERMAL PROTECTION SYSTEM SEAL DEVELOPMENT

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Overview of CEV Thermal Protection System Seal Development

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Outline

• Background
• HS-to-BS interface seal development
  – Objective and approach
  – Design
  – Testing and modeling
  – Results
• Compression pad seal development
  – Objective and approach
  – Design
  – Testing
• Summary
Apollo seals: High temp RTV (very good for sealing, good ablative properties, not much stroke), Max leakage rate ~5 lb/day, stiffer support structure → structural movements minimized

Orion seals: ~30% bigger in diameter, Because some missions may be up to 6-mo. or even longer, leakage requirements are much more stringent
Heat Shield-to-Back Shell Interface Seal System
Highlight seal design is recent
Seal is attached to Inconel diving board for easy of installation
Objective & Approach

Objective:
Develop required databases to support successful design and implementation of the CEV heat shield-to-back shell interface seal

Approach:
- Identify candidate seal designs
- Perform tests to screen and validate seal candidates
  - Coupon-level
  - Arc Jet
- Conduct thermal analyses to aid in design
- Provide recommendation to prime contractor
During reentry, heat distribution is non-uniform
Seal design has evolved continuously since project inception
Phase I: Results Summary

- **Loads**
  - Goal: ≤ 20 psi
  - Gap filler: 8 - 12 psi (57% compression)
  - Thermal barrier: 3 - 4 psi (20% compression)
  - Pressure seals: 5 – 7 psi (43% compression)

- **Leakage rates**
  - Note: Leakage rates reported at 1.0 psid
  - Gap filler: 0.3 – 6.8 SCFM/in.
  - Thermal barrier: 0.4 – 1.3 SCFM/in.
  - Pressure seals: 5.8x10⁻⁵ – 1.1x10⁻⁴ SCFM/in.
    - Less than 3% of that for the thermal barrier / gap filler
    - Effective gaps: 0.0004 – 0.003 in.

- **Temperature**
  - Elastomer pressure seal exhibited most sensitivity to temperature extremes (next slide)
  - Gap filler showed limited load retention at 2600°F
  - Spring tube thermal barrier exhibited good load retention at 1100°F

Results are applicable to next generation (HTB) seals
During all mission phases, seals maintained contact with opposing surfaces
Phase II: Evaluations

**Purpose:** Testing of evolved seal design in representative interface configuration

**Seal Configuration:** Integrated hybrid thermal barrier, silicone foam gasket

**Tests and Analyses:**
- Exploratory compression tests
- Alt. TPS material flow tests
- Alt. TPS material seal compression tests
- QARE rig tests
- Seal attachment evaluations
- Installation verification tests
- Ongoing thermal analyses

**Status:** In process
Phase II Results:
Hybrid Thermal Barrier Flow Results

Flow per inch of seal (SCFM/in.) vs. Delta P (psid)

Notes:
1) $R_s$ (roughness) values for each heat shield candidate shown in parentheses
2) $R_s$ for AETB-8 = 185 μin. (all trials)

Seal Leakage Tests

Cover plate
CEV ablator sample (PICA, Densified PICA, Avcoat)
Test seal (AETB-8 panel underneath seal sample)
Spacer plate
**Thermal Modeling: Background**

**Goals of analysis:**
- Develop model simulating flow and heat transfer through seal system
- Establish bounds on allowable leakage through seal system based on internal temperature limits

**Parameters:**
- Thermal model based on worst case (windward) geometry
- Pressure seal effective leakage varied
  - 0.001 in.
  - 0.005 in.
  - 0.020 in.
- Key Monitor Points

Orion seal thermal model geometry (PICA version)
Thermal Modeling: Representative Results

- Results shown for PICA heat shield configuration (0.375 in. gap height)
- Monitor point on shim (M6)
  - Examined temperature of edge of pressure seal
  - Temperatures below 550°F bond line limit for all cases
  - Lower temperatures realized with better pressure seals
- Monitor point on flange (M8)
  - Examined temperature of gas impinging upon hypothetical aluminum flange (e.g., helium or RCS tank)
  - Temperature limit defined by RCS tank requirements; may be 125-200°F range

Data plots showing temperature over time for different cases.
Compression Pad Seals
Compression Pad Seal Development

**Compression Pads (CP)**
- Role: Main structural connection points between CEV and SM
- Need for seals
  - CP's are different material than heat shield
  - CP's are exposed to very high heating rates

**Approach & Seal Evaluations**
- Objective: Provide seal recommendation
- Seal attributes
  - Similar to HS-to-BS seal plus ...
  - Ablation rate similar to HS and CP's
- Candidates: Silicone foam (or other) materials
- Preliminary testing
  - Compression test (low and high temp.)
  - Flow tests
  - System level arc jet tests

Heat shield
Seal/gasket
Compression Pad
Summary

• NASA GRC supporting design, development, and implementation of numerous seal systems for the Orion CEV
  – HS-to-BS interface
  – Compression pad
• HS-to-BS Interface Seal System
  – Design has evolved as a result of changes with the CEV TPS
  – Seal system is currently under development / evaluation
    • Coupon level tests
      – Loads
      – Thermal capabilities
      – Leakage resistance
      – Bond strength tests
    • Arc jet tests
    • Validation test development
• Compression Pad
  – Finalizing design options
  – Evaluating material candidates