N93-22114

Thermal Protection Materials at NASA Ames Research Center

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for the
Entry Systems Panel
Space Transportation Structures and Materials Technology Workshop
September 23-26, 1991
Omni Hotel
Newport News, VA

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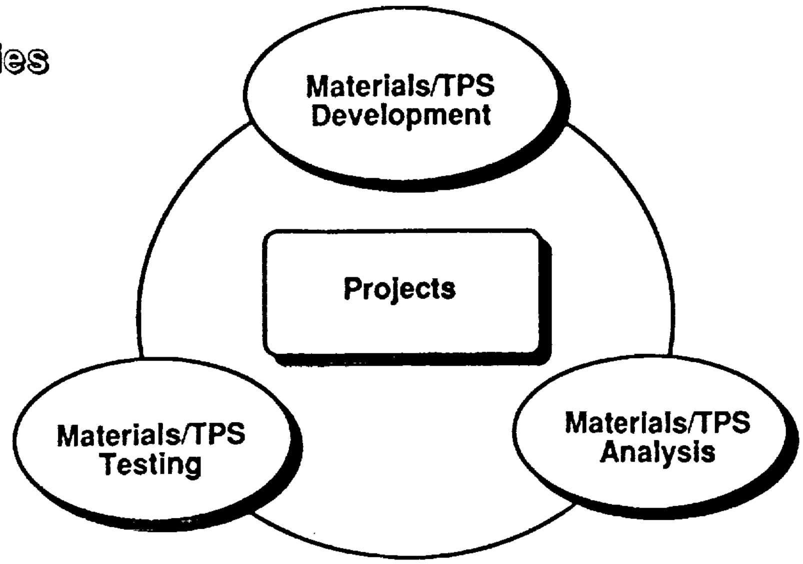
Activities



- A Synergistic, Multidisciplinary Approach
- Continual Research/Technology Development Supports Projects

Projects

- **Space Exploration Initiative (SEI)**
  Development of advanced TPS (reusable, ablative) for aerobraking applications.
- **Aeroassist Flight Experiment (AFE)**
  Wall Catalysis (WCE), AlternateThermal Protection Materials (ATPM), and Heat Shield Performance (HSP) experiments.
- **Mars Environmental Survey (MESUR)**
  Heat shield analyses and design.
- **National Aero-Space Plane (NASP)**
  Internal Insulation (#95) and arc-jet testing (#93) government work packages.
- **Pegasus and Pegasus/SWERVE Hypersonic Testing**
  Fabricating Wing Glove. Performing vehicle leading edge and heat shield analyses and arc-jet testing.
- **Personnel Launch System TPS evaluation**
  Initial TPS evaluation.

Material/TPS Testing Areas

- Arc-Jet Testing
  - Aerodynamic Heating Facility
  - Interactive Heating Facility
  - Panel Test Facility
- Material Characterization
  - XRD, SEM, XRF, Optical Microscopes
  - Dilatometer, Large Sample TGA
  - Infrared & Ultraviolet Spectrometers
- Special Testing
  - Laser Time-of-Flight Mass Spectrometer
  - Side Arm Reactor
  - Radiant Heating

Material/TPS Analysis Areas

- Computational Surface Thermochemistry
  - Surface catalysis (BLIMPK, AMIR, LAURA, VSL)
  - Ablation and shape change (ASC, CMA, ACE)
- Computational Materials
  - CVD/CVI Processing (GENMIX, NACHOS)
  - Reflective TPS analyses
  - Material properties (MATX)
- Computational Solid Mechanics
  - Multi-dimensional conduction/radiation Analysis (PATRAN, SINDA, TRASYS)

Material/TPS Development Areas

- Ceramic Matrix Composites
  - Very-High Temperature Ceramics (HfB_2 +SiC)
  - High Temperature, High Strength Ceramics (C/SiC)
  - TOPHAT CMC/Rigid Tile TPS
  - Polymer Precursors (Si/C/B fibers)
- Lightweight Ceramic Insulations
  - Rigid Tiles (AETB, METB, SMI)
  - TUFI Rigid Tile TPS
  - TABI and CFBI Flexible Blanket TPS
  - Aerogel Studies
- Lightweight Ablators
  - Polymer Filler + Rigid Ceramic Insulation
- Surface Coatings
  - Low Catalytic Efficiency, High Emissivity
  - Reflective

Diboride Materials

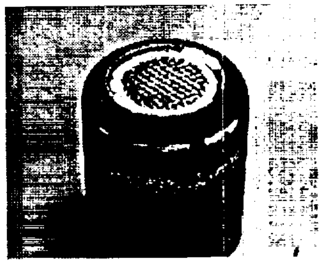
- Manlabs Inc. (Cambridge MA) tested and compiled a data base on a large number of refractory materials in the 60's and early 70's
- The diborides of zirconium and hafnium (ZrB_2 and HfB_2) were found to be the most oxidation resistant, high temperature materials in the study, e.g.

Arc testing of ZrB_2 + 20 v/o SiC
surface temp. 2510 C, stagn. press. 1.0 atm, stagn. enthalpy 11.6 kJ/gm
recession: 0.66 mm/2 hrs equivalent graphite recession: 30 cm ! equivalent SiC recession: 45 cm !

"These results illustrate the reuse capability of the boride composites... This capability is unrivaled by any other material system." - Quote from Dr. Larry Kaufman, Principal Investigator in the Manlabs Studies

Post-Test Photographs of RCC and ZrB_2 + 20 v/o SiC Samples

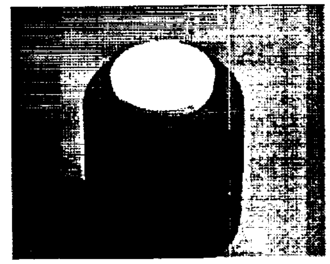
Test Conditions: test time = 3 min, cold wall heat flux = 270 W/cm^2, stag. press. = 0.046 atm, stag. enth. = 25 kJ/gm



LTV-t1n2a
RCC

Recession: 2.0 mm
Weight loss: 1.31 gm
Peak temp.: 2040 C

SiC coating lost after approximately 100 sec.



Cerac-t2n4a
ZrB_2 + 20v/o SiC

Recession: -0.03 mm
Weight loss: 0.01 gm
Peak temp.: 1820 C

Adherent, thin, glassy coating formed on sample

Maximum Cold Wall Heat Flux Computations

- For one-dimensional, radiative equilibrium, the maximum cold wall heat flux, Q_{cw}, can be computed from the maximum material use temperature, T_{max}, by:

$$Q_{cw} = \varepsilon\sigma T_{max}^4/(1 - H_w/H_r)$$

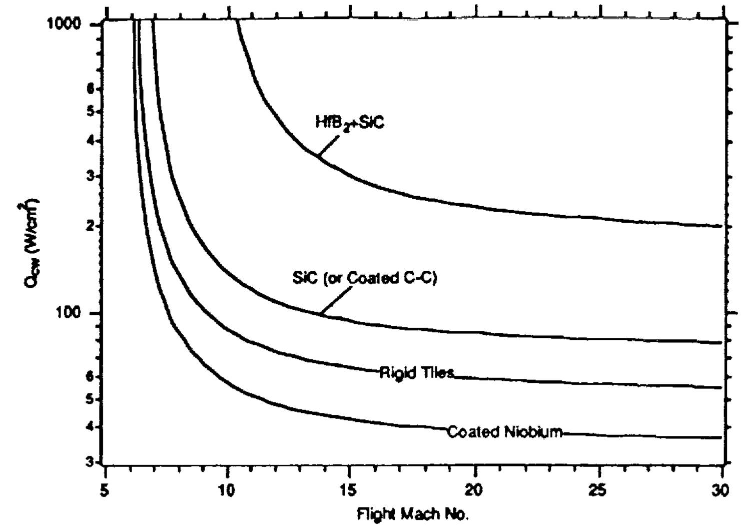
where ε is the emissivity and H_w is the wall gas enthalpy at T_{max}, and H_r is the local recovery enthalpy

- With values for the material maximum use temperature and emissivity, Q_{cw} can be easily computed

Material	Maximum Use Temp. (C)	Emissivity
HfB_2+SiC	2480	0.62
SiC (or Coated C-C)	1760	0.76
Rigid Tiles	1540	0.85
Coated Niobium	1530	0.65

Maximum Cold Wall Heat Flux Computations (Cont.)

Q_{cw} for a Fully Catalytic Surface*



* Non-catalytic surface effects can considerably increase Qcw from the values show (i.e. can substantially increase Hw)

Major Goals

- New very-high temperature ceramic matrix composites/TPS for 4000+ F reusability (Zr and Hf ceramics)
- High strength ceramic matrix composites for structural TPS applications at 3000+ F (SiC/TiB2 matrix ceramics)
- Durable, lightweight ceramic TPS for 3000+ F use (TUFI, TOPHAT)
- Lightweight, rigid, ceramic insulations for 3000+ F use (AETB, METB, SMI)
- Flexible lightweight ceramic insulations/TPS for 2500+ F use (TABI, CFBI)
- New very lightweight ablators with 20-30% weight savings compared to state-of-the-art materials
- High emissivity, low surface catalytic efficiency, and reflective coatings for advanced TPS
- New 3-D computational surface thermochemistry (CST) code for predicting detailed near surface fluid/material response interaction for advanced TPS/vehicle analyses

10.3.11 Some Materials Perspectives for Research for Space Transportation Systems by Howard G. Maahs, NASA LaRC