THERMAL BARRIERS

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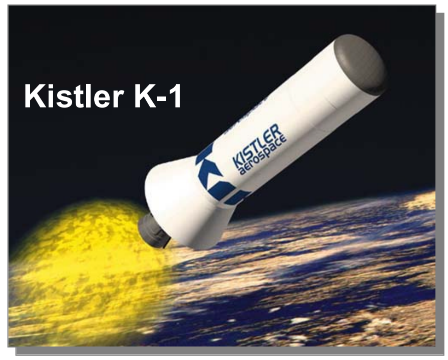
Introduction

- **The thermal barrier designs included in this presentation were developed for Orbital Sciences Corp., Dulles, VA and Kistler Aerospace Corp., Kirkland, WA**



Introduction of launch vehicles that use the presented thermal barrier designs

Introduction

- OTS projects involving thermal barrier design, fabrication, and test
  - Orbital Sciences X-34
  - Lockheed Martin Skunkworks X-33
  - Kistler Aerospace K1
- RLVs require doors in the external surface of the vehicle
  - Locations include: landing gear, umbilical connections, compartment venting, payload compartments
  - Design Elements
    - Open and/or close during the flight which can include ascent, on orbit and reentry phases
    - Perimeter gaps are relatively large due to hinged action and tolerances
    - TPS includes thermal barriers at the door perimeter gaps to prevent excess heating of the vehicle structure and pressure seals due to hot gases entering the gaps
    - Pressure seals are typically present at the door structure to prevent gas flow into the vehicle due to delta P

Projects supported by Oceaneering Thermal Systems

Key features of RLV doors that drive thermal barrier designs

Introduction

- Panels (for reference only - not part of this presentation)
  - Locations include: umbilical connections, maintenance access and ground operations
  - Typically removed on the ground during vehicle turnaround
  - Can have blanket TPS simply snug fit to surrounding TPS or include a perimeter Gap Filler

Key features of RLV doors that drive thermal barrier designs

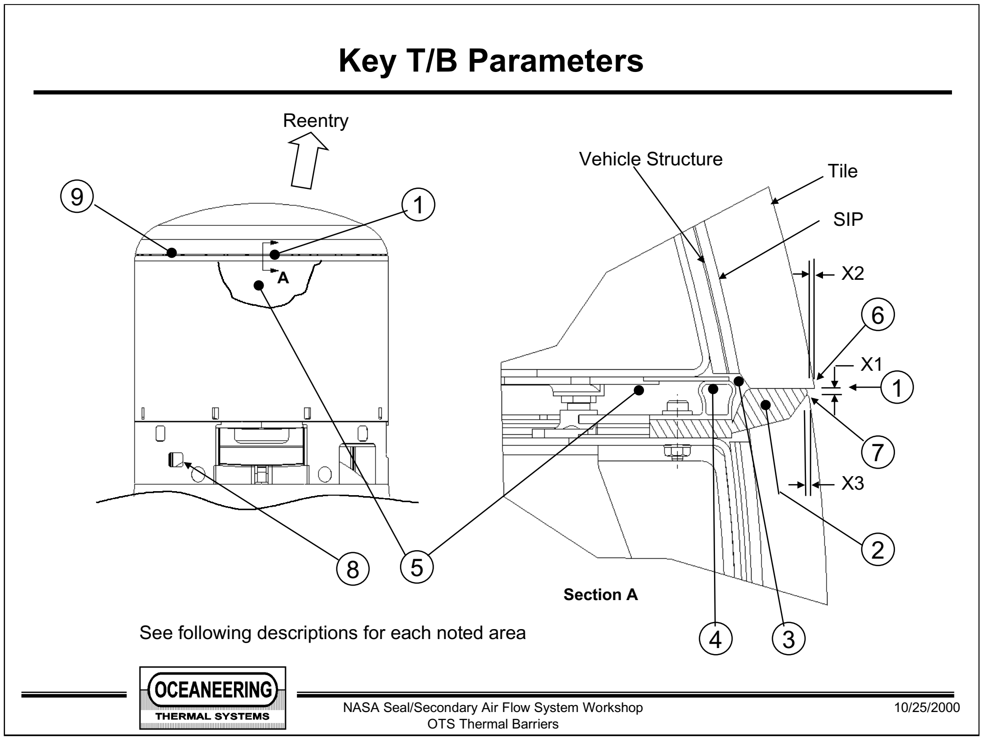


Illustration for a description of typical thermal barrier functions

Thermal Barrier Parameters

(1) Gap in surface of OML at perimeter of an actuated door
- Reentry causes heating at gap surface
- Applicable design parameters are heat, temperature, local pressure and delta pressure across and along T/B

(2) and (9) Thermal Barrier (T/B)
- Fills the gap between structure TPS and door TPS
- Provides thermal insulation for underlying structures
- Restricts air flow in the gap parallel and transverse to T/B length
- Compensates for wider gaps and larger gap tolerances than gaps in acreage TPS
- Maintain gap side wall contact to prevent unrestricted air flow into cavity (3)
  - "sneak" flow occurs through cavity (3) if there is a pressure differential between two locations (1) & (9) and there is a lack of wall contact at each location

Parameters affecting typical thermal barrier functions

Thermal Barrier Parameters

(3) Cavity between T/B and pressure seal

- Size minimized to limit amount of total heat when this space is repressurized
- Size minimized to restrict flow parallel to T/B
- Structure along this cavity will absorb and dissipate small heat flow

(4) Pressure (Environmental) Seal

- Prevent flow through the T/B caused by pressure differential between (1) and (5)

(5) Vehicle inner volume

- Vented during ascent and reentry via vents (8)
- Vent (8) is typically closed during maximum reentry heating period
- Analyze components exposed to direct flow from the vent

Parameters affecting typical thermal barrier functions

Thermal Barrier Parameters

(6) & (7) Forward and aft sides of TPS gap

- Increasing OML step (X2) increases protuberance heating
- Wider gap (X1) increases protuberance heating
- Wider gap (X1) exposes additional T/B materials to heating which increases total heat absorbed by the T/B
- Wider gap (X1) increases heating to the sides of gap
- Gap side walls see heating due to radiation from opposing wall (radiation trap)
- Deeper gaps (X3) increase gap wall heating due to reduced view factor to space
- Allowable step is primarily relative to the local boundary layer thickness
- Allowable gap width is primarily relative to the local flowfield pressure gradients and the surface geometry

Parameters affecting typical thermal barrier functions

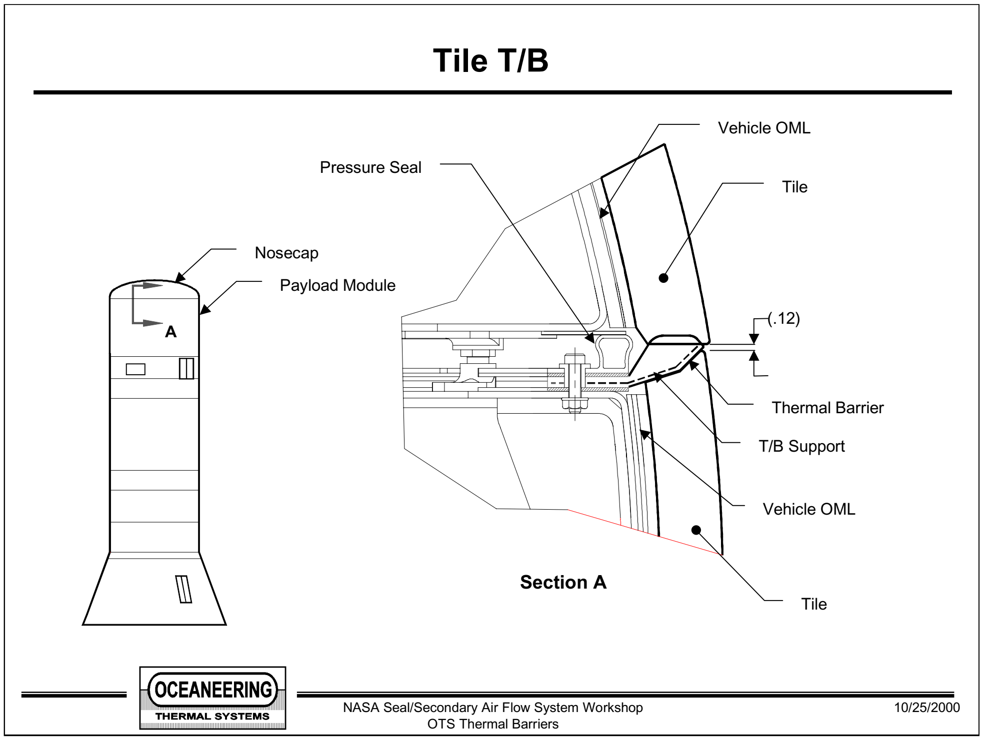


Illustration of a tile to thermal barrier interface

Tile T/B

Design

- Typically windward side use
- Compressed between TPS tile
- Multiple Nextel sleeves w/ Inconel mesh tubes filled with Saffil
- T/B support to maintain position w/o the use of adhesives
- TPS surface temperature capability up to 2400ºF
- Maximum structure temperature = 350°F
- Heating from orbital reentry near vehicle leading edge
  - Design similar to nose gear door T/B on the Space Shuttle

Status

- Development unit built to develop manufacturing techniques
- Compression testing of development unit performed to confirm loads and seal location stability
- 2D thermal analysis is complete
- Arc jet testing is planned

Design and status of a tile to thermal barrier interface

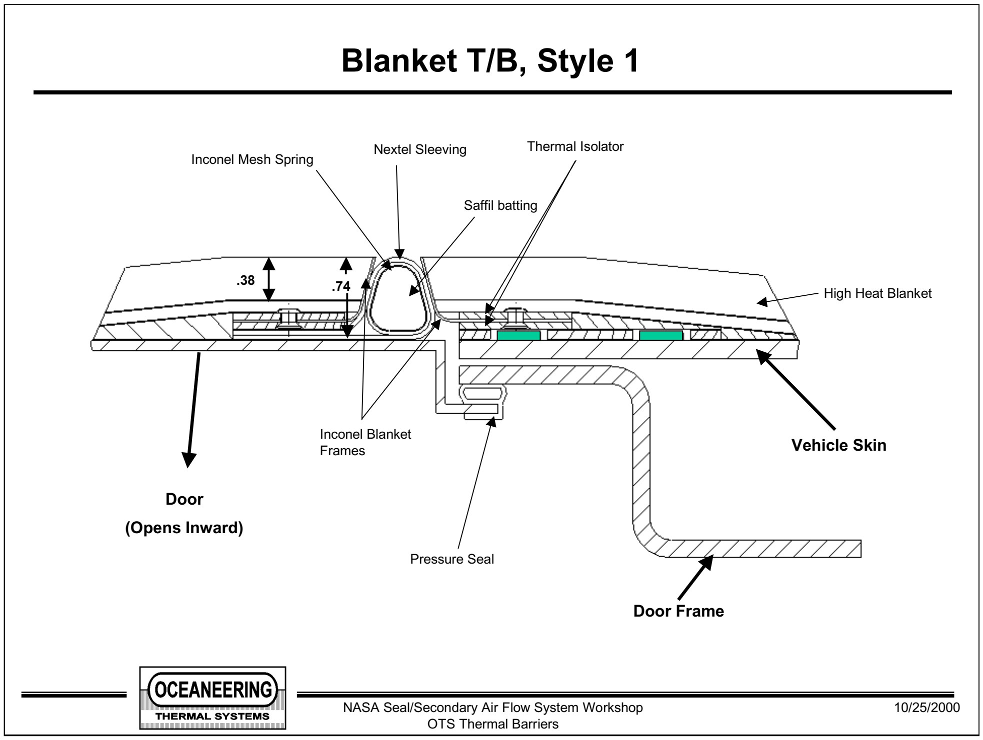


Illustration of a blanket to thermal barrier interface

Blanket T/B, Style 1

Design

- Leeward or windward side use
- External Inconel reinforced blanket edges to compress T/B
- Inconel sandwiched to thermally isolate from RTV
- Single Nextel sleeve, Inconel mesh tube and Saffil
- Inward opening door
- TPS surface temperature up to 1250º F as shown, 1500° F being evaluated
- Maximum structure temperature = 350° F
- Heating durations for reentry from orbit
- High Heat Blanket (HHB) is Nextel 440 OML with Saffil Insulation

Status

- Concept complete
- 2D thermal analysis complete
- Development unit planned
- No thermal testing planned

Design and status of a blanket to thermal barrier interface

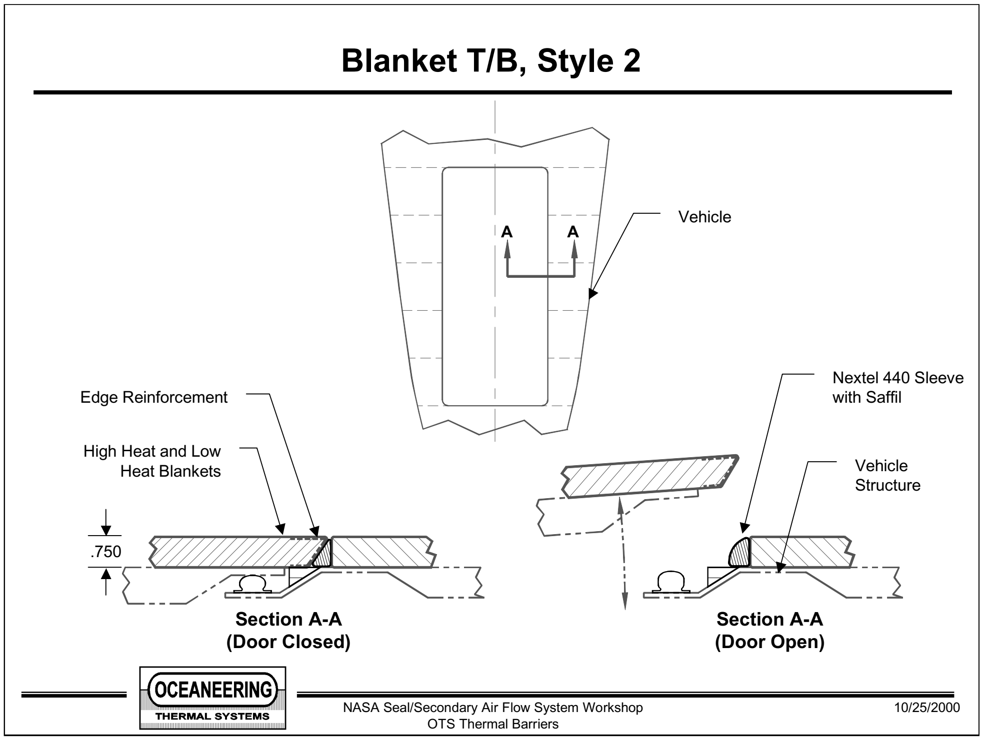


Illustration of a blanket to thermal barrier interface

Blanket T/B , Style 2

Design

- **Leeward or windward side use**
- **Internal reinforced blanket edges to compress T/B**
- **Nextel 440 sleeve and Saffil**
- **Outward opening door**
- **TPS surface temperature up to 1000º F for LHB, 1700°F for HHB**
- **Maximum structure temperature = 300°F**
- **Heating durations for suborbital reentry**
- **Low Heat Blanket (LHB) is Astroquartz OML with Q-Felt insulation**

Status

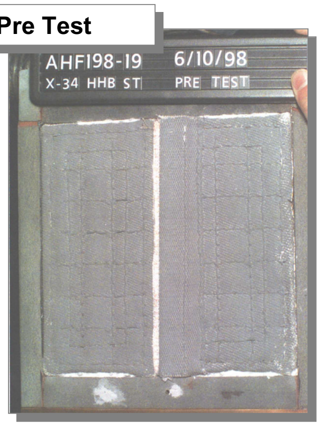
- **Design qualified and drawings released**
- **Flight units built and delivered**
- **Arc jet testing complete**
- **Installation and flight planned**

Design and status of a blanket to thermal barrier interface

Blanket T/B, Style 2

- **Arc Jet test coupons for Style 2 T/B**
- **Aerodynamic Heating Facility at NASA ARC**
- **Test results indicate T/B protected the structure**

Pre Test

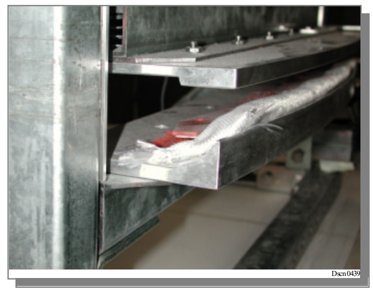


Post Test

Description and photos of thermal barrier arc jet test coupon

Tile Thermal Barrier Test Fixture

- T/B test articles up to 24 inches long
- Replaceable interface plates for different T/B designs
- Load cell readout for compression loads
- Indicator for deflection measurements



Description and photos of a thermal barrier compression test fixture

Space Shuttle Tile T/B Inspection

Procedure

- **Mylar pull test**
  - **Initial installation**
    - **Mylar strip pulled from between the tile and T/B at the center of every tile - nose gear (NG), main gear (MG) and external tank (ET)**
  - **Performed every flight**
    - **NG door due to potential changes from high heating**
    - **ET door because black RTV is recoated on T/B every flight**
    - **MG door is not checked every flight**
- **Flow path checks are performed every flight at NG, MG, ET door tile**
  - **Consists of pushing a .010 shim between the T/B and tile to ensure no gaps exist**
  - **Checks made along full length of each tile**

Description of Space Shuttle thermal barrier installation inspection

Closing

Updates in work for thermal barriers on the next generation launch vehicles

- **Enhanced durability to reduce replacement**
- **Enhanced reliability to reduce inspection needs**

Thermal barrier upgrades in work for next generation RLVs