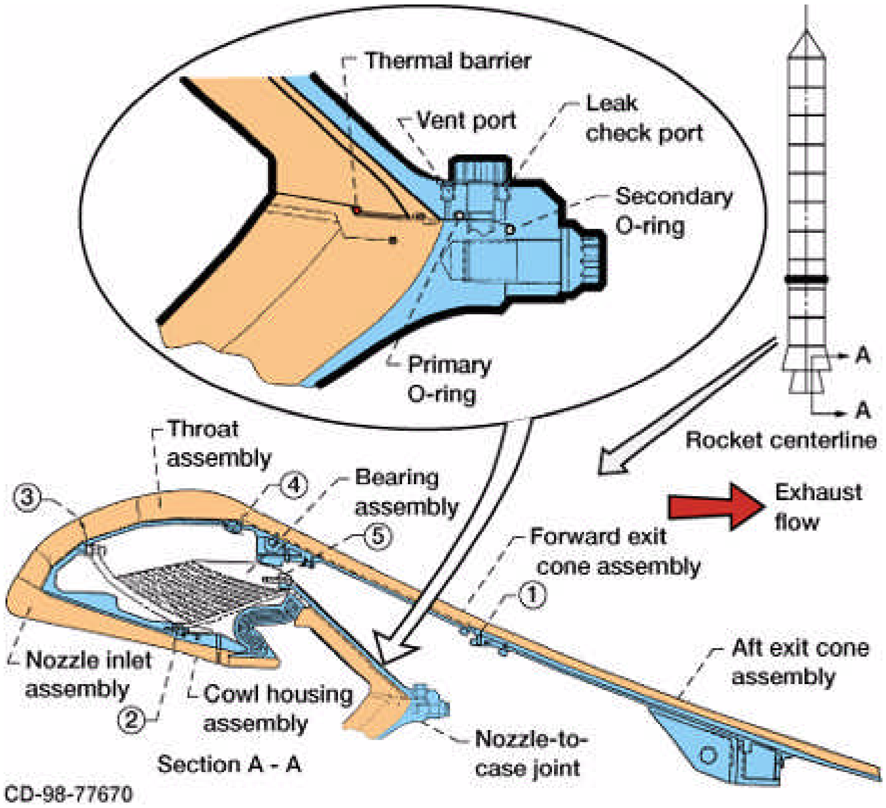
NASA Lewis Thermal Barrier Feasibility Investigated for Use in Space Shuttle Solid-Rocket Motor Nozzle-to-Case Joints

Assembly joints of modern solid-rocket motor cases are usually sealed with conventional O-ring seals. The 5500 °F combustion gases produced by rocket motors are kept a safe distance away from the seals by thick layers of insulation and by special compounds that fill assembly splitlines in the insulation. On limited occasions, NASA has observed charring of the primary O-rings of the space shuttle solid-rocket nozzle-assembly joints due to parasitic leakage paths opening up in the gap-fill compounds during rocket operation. Thus, solid-rocket motor manufacturer Thiokol approached the NASA Lewis Research Center about the possibility of applying Lewis' braided-fiber preform seal as a thermal barrier to protect the O-ring seals. This thermal barrier would be placed upstream of the primary O-rings in the nozzle-to-case joints to prevent hot gases from impinging on the O-ring seals (see the following illustration). The illustration also shows joints 1 through 5, which are potential sites where the thermal barrier could be used.

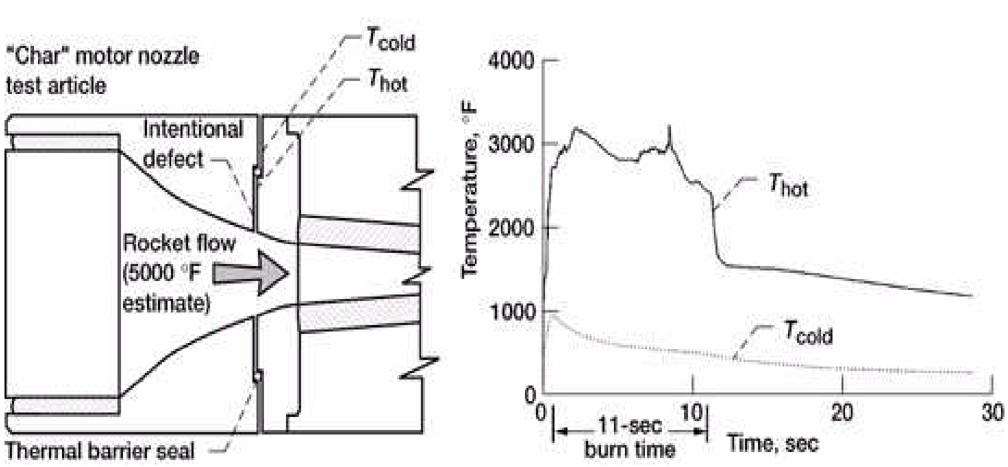


Potential shuttle solid-rocket motor joint locations (circled numbers) for candidate thermal barrier. Top: Enlarged view of nozzle-to-case joint showing primary and secondary pressure O-rings, leak-check part, and proposed thermal barrier location. Bottom: Overall nozzle cross section (half view).

Burn tests at temperatures representative of the rocket thermal environment were used to evaluate the thermal resistance of braided rope thermal barriers made of different materials. Thermal barriers were placed in the hottest part of the flame of an oxyacetylene torch at 5500 °F, and the amount of time to completely cut through them was measured. A 0.125-in.-diameter stainless steel rod was cut through in 5 sec, whereas 0.125-in.-diameter thermal barriers of braided ceramic and superalloy materials lasted less than 15 sec. In contrast, 0.125-in.-diameter thermal barriers of braided carbon fibers lasted over 2 min. Carbon-fiber thermal barriers with diameters of 0.200 and 0.260 in. lasted over 6.5 and 8.5 min., respectively, before they were cut through (see the following photo). As a point of reference, the solid-rocket motors of the space shuttle only burn for 2 and 4 sec, much shorter than the burn-through times of the carbon-fiber thermal barriers. On the basis of these results, the decision was made to use carbon fibers to braid the thermal barriers.

Candidate thermal barrier (0.2-in. diameter) for shuttle solid-rocket motor in 5500 °F oxyacetylene burn test. Time for burn through, 6.5 min.

Flow tests performed on the thermal barriers showed that they blocked hot gas flow but were permeable enough to allow leak checks of the primary/secondary O-ring system. The barriers also were resilient enough to accommodate flange movements in the solid-rocket motor. To simulate a rocket environment, Thiokol performed subscale rocket "char" motor tests in which the thermal barrier was subjected to hot gases that flowed through an intentional 0.060-in. circumferential gap defect both upstream and downstream of the thermal barrier. During the 11-sec rocket firing, temperatures over 3200 °F were measured on the hot side of the 0.260-in.-diameter thermal barrier, whereas temperatures on the cold side were just over 950 °F for a temperature drop of over 2200 °F across the thermal barrier (see the graphs).



Preliminary subscale (70-lbf thrust) "char" motor tests examining thermal barrier effectiveness. Left: Test configuration: thermal barrier (0.125-in. diameter) filling an intentional joint defect. Right: Temperature data: upstream (T_{hot}) and downstream (T_{cold}) sides of thermal barrier. (Copyright Thiokol Corp.; used with permission.)

On the basis of these results, additional mechanical and thermal testing is planned at Lewis to help further characterize the thermal barrier. Thiokol is planning to test the thermal barrier in a subscale solid-rocket motor, where it would be installed first in its undamaged state and then with an intentional defect (Spring and Fall 1999). If all planned tests show success, the Lewis-developed thermal barrier would be prepared for Full Scale RSRM static tests in November 2000 (no-joint defect) and May 2002 (with joint defect); it would be subsequently qualified for flight.

Bibliography

Steinetz, B.M.; and Dunlap, P.H.: Feasibility Assessment of Thermal Barrier Seals for Extreme Transient Temperatures. AIAA Paper 98-3288 (NASA TM-1998-208484) 1998.

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Special recognition: 1996 NASA Invention of the Year awarded to the fiber preform seal, precursor to the thermal barrier seal